Sweet corn information kit

Reprint – information current in 2005

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.deedi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 2005. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.deedi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

This publication was last revised in 2005. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

Queensland Government

Chapter 4

Key ISSUES

This chapter contains more detailed information on some of the important decision-making areas and information needs for sweet corn. The information supplements our growing and marketing summary in Chapter 3 and should be used in conjunction with it. The information provided on each issue is not designed to be a complete coverage of the issue but instead the key points that need to be known and understood. Where additional information may be useful, we refer you to other parts of the book. Symbols on the left of the page will help you make these links.

Contents

Keys to making a profit

For most growers, the primary aim of their farming business is to make a profit. The secondary aim is to maximise that profit. This section provides an overview of the key elements in achieving maximum profits.

The simple profit equation

In simple terms:
Profit = Returns – costs

Therefore to achieve maximum profits you need to **increase returns** and **reduce costs.** The potential impact on profit of each of these is discussed below.

Increase returns

More efficient production by, for example, increasing yields, greater mechanisation (reducing labour cost) and improving quality will all help increase returns.

Your returns are influenced by:

- the price you receive;
- the quantity you sell.

Price received

The price received for sweet corn is influenced by the:

- quality of the cobs on arrival in the market;
- presentation (appearance/grade/package);
- demand (volume/variety/alternatives);
- market destination of the cobs;
- long-term reputation of your product;
- or for processing crops, the contract price.

Sweet corn quality

Quality of sweet corn is essentially determined by five factors:

Colour. The best prices are paid for the colour characteristics required by a particular market. The main demand is for large, golden yellow kernels, but there is a small market for bi-colour and white sweet corn. The preferred husk colour is mid-green.

Size. The best prices for fresh market sweet corn are paid for cobs that weigh about 350 g; that is about 24 to 30 cobs per 9 kg package.

Cleanliness and appearance. The best prices are paid for cobs that are free from any marks or blemishes that affect appearance. Marks, blemishes, insect damage and rots detract from appearance substantially. The husk should look fresh, with no flag leaf.

In most fruit and vegetables external appearance is the main factor influencing a consumer's decision to purchase. The product must look inviting for the consumer to place it in their shopping trolley.

Eating quality. A recent survey indicated that sweet corn buyers were generally satisfied with the taste of sweet corn. There were however significant numbers of buyers who suggested that it would be better if it were sweeter, fresher, juicier, fuller flavoured or more tender.

If a consumer takes a product home and its performance does not match their expectations, they will not buy your product again, so you will lose repeat business. People now consume increasing amounts of gourmet foods, and eating and preparing food is a fashionable past time, so flavour and eating quality will become increasingly important.

Soundness and shelf life. The best prices are paid for cobs that are sound and stored properly in order to maximise shelf life. A measure of soundness commonly used by consumers is a fresh, green husk.

These quality characteristics are influenced by a number of pre-harvest and postharvest management practices, some more significantly than others. The impact of these management practices on quality is summarised in Table 35.

Table 35. Impact of pre and post harvest management practices on sweet corn quality

Management practice	**Impact on quality (5 = high impact; 1 = low impact; – = not applicable)**				
	Kernel colour	**Cob size**	**Husk cleanliness and appearance**	**Eating quality**	**Shelf life**
Variety	5	4	3	5	1
Pre-harvest					
Nutrition	–	4	3	1	1
Irrigation	–	4	1	1	1
Pest/disease management	–	–	5	–	4
Harvest					
Maturity stage	4	1	1	5	4
Harvesting	–	1	3	–	3
Postharvest					
Grading and packing	–	–	4	–	–
Storage	1	–	3	4	5
Packaging	–	–	3	–	3
Transport	–	–	3	3	4

Market destination

Different markets have different price opportunities for the various product types. The key is to research all market options well in order to match the type of product you can produce (dependant on environment and management system) to the best market opportunity. This includes determining your potential competitors and when their product reaches the market.

The role of the central markets is diminishing as the major retailers now dominate the sales of sweet corn. These major customers, the big retailers, are looking for suppliers who can supply large volumes of a consistent specification over an extended period. Therefore growers need to either align themselves with the major merchants who supply these chains, or develop direct relationships with the retailers. The majority of growers will not be able meet the supply expectations of these larger customers on their own.

Processing crops are grown in New South Wales and southern Queensland under contract to the processor.

Reputation

Products often receive a higher price because of their past reputation. A product that has been consistent in quality and supply, year after year, is usually bought first and often at the highest price. This is particularly important during periods of oversupply and low prices. Gaining a good reputation is very dependent on implementing a quality management program throughout your production and marketing system. Packing into easily identifiable or well branded containers may also help you build a recognised presence in the market.

Volume sold

The other way of increasing returns is to increase the volume of marketable cobs sold. Increasing production usually requires some additional costs, but don't spend more money to increase production than you can recoup from increased sales. The volume sold depends on both the quantity of cobs produced and the demand for them on the market.

Customer demand can be affected by the volume of sweet corn on the market, the price and the alternative products available. The main management factors affecting the volume of marketable cobs produced and sold are listed in Table 36.

Table 36. Impact of management factors on volume of sweet corn cobs produced and sold

Management factor	Impact on marketable volume of cobs (5 = high impact; 1 = low impact)	
	Marketable volume produced	**Volume sold**
Variety	3	2
Area planted	5	4
Nutrition	1	1
Irrigation	2	1
Pests and diseases	3	3
Postharvest handling	–	4
Quality	–	4
Reputation	–	3
Demand	–	5

Reduce costs

Reducing costs may not be a practical way of increasing profit. Unless you are careful in where you reduce costs, you may reduce production and/or quality, and therefore your income, by more than you save. The first step in reducing costs is to know where the major costs occur.

Typical costs of producing a 1100 package per hectare sweet corn crop in southern Queensland are shown in Table 37. These figures assume that 40% of the cobs are undamaged and marketed in loose packs at $11 per 18 L package, and 60% need trimming and are sold in pre-packs at $16 per 18 L package, an average price of $14 per 18 L package on the Brisbane market.

Table 37. Costs of growing and marketing sweet corn in southern Queensland

	$/carton (loose)	$/carton (pre-pack)	$/ha
Total preharvest costs (growing)	$2.45	$2.45	$2 694
Total postharvest costs (harvest and pack)	$3.64	$7.14	$6 310
Total marketing costs (commission and levies)	$1.98	$2.60	$2 587
Total variable costs	**$8.07**	**$12.19**	**$11 591**

Cost reduction often has little impact on overall profitability. Around 75% percent of total costs are involved in harvesting, packing and marketing and it is difficult to significantly reduce these costs without affecting quality. Increasing mechanisation to minimise labour may reduce costs but requires a large capital investment.

The key to profit

The key to increasing profit appears to be in maximising returns rather than minimising costs. The most effective way of maximising returns appears to be improving the price obtained. The best chance you have of doing this is to gain and maintain a reputation for producing a high-quality product.

To do business in the sweet corn industry it is critical that you establish links with your customers and supply high quality product on a regular and reliable basis.

Negotiating supply arrangements well before planting is critical to success. Because the sweet corn market can be very fickle you are at the mercy of the open market unless you have supply arrangements in place.

Economics of production

One way of assessing the economics of sweet corn production is by calculating the gross margin for the crop. All data included in these gross margins are based on information provided to the authors. No responsibility can be taken for its accuracy. This data should be confirmed ***and changed where necessary by the user before any decisions based on the result are made.***

The following gross margins are for fresh market sweet corn grown in Bowen and southern Queensland and for a processing crop grown in New South Wales.

Assumptions

The calculations assume crops are grown with irrigation and good management. All machinery operations include costs for fuel, oil, repairs and maintenance (F.O.R.M.). No allowance is made for owner-operator labour. This gross margin template for the fresh market crops was designed for and by the Queensland Farm Financial Counselling Service.

Glossary of terms

The following terms are used in the economic data presented. You will need to make your own calculations to determine these figures for your operation.

Gross margin. A gross margin is the difference between the gross income and the variable or operating costs. The calculation does not consider fixed or overhead costs.

Variable or operating costs. These costs include the growing, harvesting and marketing costs.

Fixed or overhead costs. These costs include rates, capital, interest, electricity, insurance and living costs. These fixed or overhead costs are not included in a gross margin but must be taken into account in calculating a whole farm budget.

Break-even price. The market price at which all growing, harvesting and marketing costs are recovered but no profit or loss is made.

Break-even yield. The yield at which all growing, harvesting and marketing costs are recovered but no profit or loss is made.

Gross margin per megalitre of irrigation water. The return per megalitre of irrigation water applied.

A gross margin for fresh market sweet corn in southern Queensland

The following gross margin assumes that 40% of the cobs are undamaged and marketed in loose packs at $11 per 18 L package, and 60% need trimming and are sold in pre-packs at $16 per 18 L package, an average price of $14 per 18 L package.

Enterprise unit: 1 ha of furrow irrigated sweet corn

INCOME	Amount	$ /carton	Total $ /ha
Price (18 L styro package)		$14.00	
Packages /ha	1 100		
TOTAL INCOME			**$15 400**

VARIABLE COSTS	/ha	$/unit	$/ha	Total $/ha
Land preparation (F.O.R.M.)				
Ripping	1	$27.00 /ha	$27.00	
Disc harrowing	1	$25.00 /ha	$25.00	
Cultivation	1	$10.00 /ha	$10.00	
Machinery	1	$4.00 /hr	$4.00	
Labour (hours)	1.5	$15.00	$22.50	
TOTAL LAND PREPARATION COSTS				$88.50
Planting				
Sweet corn seed	30 kg	$35.00 /kg	$1 050.00	
Planter	1	$20.50 /ha	$20.50	
Labour (hours)	1.5	$15.00	$22.50	
TOTAL PLANTING COSTS				$1 074.50
Fertiliser				
Basal	250 kg	$0.59 /kg	$147.50	
Side-dress	200 kg	$0.50 /kg	$100.00	
Foliar fertiliser (X 2)	0.5 L	$14.00 /L	$14.00	
Machinery	1	$4.00 /hr	$4.00	
Sprayer	2	$10.00 /ha	$20.00	
Fertiliser spreader	1	$10.00 /ha	$10.00	
Labour (hours)	2	$15.00	$30.00	
TOTAL FERTILISER COSTS				$325.50
Weed control				
Herbicide	1.5 L	$33.50 /L	$50.25	
Interrow cultivation	2	$9.82	$19.64	
Sprayer ($/ha)	1	$10.00	$10.00	
Labour (hours)	1	$15.00	$15.00	
TOTAL WEED CONTROL COSTS				$94.89
Insect control				
Monitoring	9.5 hours	$50.00	$475.00	
NPV	4 x 0.5 L	$66.50 /L	$133.00	
Machinery	1	$4.00 /hr	$4.00	
Sprayer (ground)	4	$10.00	$40.00	
Labour (hours)	4	$15.00	$60.00	
TOTAL INSECT CONTROL COSTS				$712.00

VARIABLE COSTS	/ha	$/unit	$/ha	Total $/ha
Irrigation				
Water costs	4 ML	$50.00 /ML	$200.00	
Machinery	1	$4.00 /hr	$4.00	
Tractor	3	$10.00 /hr	$30.00	
Labour (hours)	11	$15.00	$165.00	
TOTAL IRRIGATION COSTS		$399.00		
TOTAL PREHARVEST (GROWING) COSTS			**$2.45 /package**	**$2 694.39**

The following harvesting and packaging costs assume that 40% of the cobs are undamaged and marketed in loose packs, and 60% need trimming and are sold in pre-packs.

POSTHARVEST COSTS		Cost	$ /package	$ /ha
Harvesting and packing costs Loose packs:	(40% of crop)			
Harvesting: equipment and labour	440	$150.00 /ha	$0.14	$60.00
18 L styro packages	440	$1.20 / pkg	$1.20	$528.00
Packing: labour	440	$2.00 / pkg	$2.00	$880.00
Cooling	440	$0.30 /pkg	$0.30	$132.00
Harvesting and packing costs	**(loose packs)**		**$3.64**	**$1 600.00**
Harvesting and packing costs Pre-packs:	(60% of crop)			
Harvesting: equipment and labour	660	$150.00 /ha	$0.14	$90.00
18 L styro packages	660	$1.20 /pkg	$1.20	$792.00
Packing: labour	660	$4.50 /pkg	$4.50	$2 970.00
Packing: equipment and materials	660	$1.00 /pkg	$1.00	$660.00
Cooling	660	$0.30 /pkg	$0.30	$198.00
Harvesting and packing costs	**(pre-packs)**		**$7.14**	**$4 710.00**
TOTAL HARVESTING AND PACKING COSTS				**$6 310.00**
Marketing costs				
Freight (to Brisbane)			$0.60	
Commission and levies	12.5%		$1.75	
TOTAL MARKETING COSTS	1 100 pkgs		$2.35	$2 587.20
TOTAL POSTHARVEST COSTS (harvesting + packing + marketing)				**$8 897.20**

SUMMARY TABLE

	$/package (loose)	$/package (pre-pack)	$/ha
TOTAL PREHARVEST COSTS	$2.45	$2.45	$2 694.39
TOTAL HARVEST & PACKING COSTS	$3.64	$7.14	$6 310.00
TOTAL MARKETING COSTS	$1.98	$2.60	$2 587.20
TOTAL VARIABLE COSTS	**$8.07**	**$12.19**	**$11 591.59**

Gross margin = Total income less total variable costs

	$/package (loose)	$/package (pre-pack)	$/ha
Total income (1 100 packages/ha)	$11.00	$16.00	$15 400.00
Less			
Total variable costs	$8.07	$12.19	$11 591.59
GROSS MARGIN	**$2.93**	**$3.81**	**$3 808.41**

The following assumes that 40% of the cobs are undamaged and marketed in loose packs, and 60% need trimming and are sold in pre-packs.

BREAK-EVEN YIELD at $14.00 (average) per 18 L package	456 packages /ha
BREAK-EVEN MARKET PRICE per 18 L package (1100 packages/ha)	$10.20 per package
BREAK-EVEN ON FARM PRICE per 18 L package (1100 packages/ha)	$8.32 per package
GROSS MARGIN per MEGALITRE of IRRIGATION WATER	$953 per ML

Actual gross margin when price or yield changes

Yield	Price per package						
packages /ha	$8.00	$9.50	$11.00	$12.50	$14.00	$15.50	$17.00
800	−2 204	−1 154	−104	946	1 996	3 046	4 096
900	−2 124	−943	238	1 419	2 601	3 782	4 963
1 000	−2 044	−732	581	1 893	3 206	4 518	5 831
1 100	−1 964	−521	923	2 367	3 811	5 254	6 698
1 200	−1 884	−309	1 266	2 841	4 416	5 991	7 566
1 300	−1 804	−98	1 608	3 314	5 021	6 727	8 433
1 400	−1 724	113	1 951	3 788	5 626	7 463	9 301
1 500	−1 644	324	2 293	4 262	6 231	8 199	10 168

Enterprise characteristics

Growing risk	Medium
Price fluctuations	Medium
Working capital requirement	Medium – High
Harvest timeliness	High
Management skills	High
Quality premium	Yes
Spray requirements	Moderate – High
Labour requirements—growing	Low
Labour requirements—harvesting	Medium

Last update: February 2004

A gross margin for fresh market sweet corn in Bowen, north Queensland

This gross margin assumes that all marketable cobs are sold loose in 18 L packages.

Enterprise unit: 1 ha of drip irrigated sweet corn

INCOME	Amount	$ /package	Total $ /ha
Price (18 L styro package)		$11.00	
Packages /ha	950		
TOTAL INCOME			**$10 450**

VARIABLE COSTS	/ha	$/unit	$/ha	Total $/ha
Land preparation (F.O.R.M.)				
Ripping	1	$45.00 /ha	$45.00	
Disc harrowing	2	$38.00 /ha	$76.00	
Rotary hoeing	1	$30.00 /ha	$30.00	
Cultivation	2	$10.50 /ha	$21.00	
Labour (hours) includes on costs	7	$14.50	$101.50	
TOTAL LAND PREPARATION COSTS				$273.50
Planting				
Sweet corn seed	55 000 /ha	$7.50 /100 000	$412.50	
Planter (includes fertiliser & herbicide app.)	1	$38.00 /ha	$38.00	
Labour (hours)	3	$14.50	$43.50	
TOTAL PLANTING COSTS				$494.00
Fertiliser				
Basal fertiliser	500 kg/ha	$0.51 /kg	$255.00	
Urea – through drip (3 applications)	3 x 50 kg/ha	$0.42 /kg	$63.00	
Solubor – foliar in 400 L/ha (2 applications)	2 x 1 kg/ha	$5.12 /kg	$10.24	
Zinc sulphate heptahydrate – at planting	40 kg/ha	$1.09 /kg	$43.60	
Soil analysis	1 per 4 ha	$100.00 /ha	$25.00	
Spraying – ground rig	3	$8.20 /ha	$24.60	
Labour (hours)	3	$14.50	$43.50	
TOTAL FERTILISER COSTS				$464.94
Weed control				
Herbicide- banded	1.2 L/ha	$18.60 /L	$22.32	
Sprayseed - interrows	1.6 L/ha	$11.00	$17.60	
Interrow spraying	1	$8.00	$8.00	
Labour (hours)	2	$14.50	$29.00	
TOTAL WEED CONTROL COSTS				$76.92
Insect control				
Insecticide 1	0.7 L/ha	$12.25 /L	$8.58	
NPV	4 x 0.5 L/ha	$77.00 /L	$154.00	
Insecticide 2	6 x 2 L/ha	$11.00 /L	$132.00	
Insecticide 3	2 x 0.4 L/ha	$156.00 /L	$124.80	
Insecticide 4	2 x 0.25 L/ha	$60.00 /L	$30.00	
Insecticide 5	0.75 L/ha	$8.95 /L	$6.71	
Spraying – ground rig	10	$8.20	$82.00	
Labour (hours)	10	$14.50	$145.00	
Crop scouting (monitoring)		$120.00 /ha	$120.00	
TOTAL INSECT CONTROL COSTS				$803.09

VARIABLE COSTS	/ha	$/unit	$/ha	Total $/ha
Irrigation				
Water charges - Bowen	4 ML /ha	$3.80 /ML	$15.20	
Power: single (30 kw pump)	40 L/sec	$0.05 /kw hr	$41.67	
Drip tape (10 mm)	6 600 m/ha	$0.10 /m	$646.80	
Layflat (4”, 5 year life)	50 m/ha	$4.00 /m	$40.00	
Labour – irrigation & fertigation (hours)	5 hr/ha	$14.50	$72.50	
Laying & removing drip tape	5 hr/ha	$14.50	$72.50	
TOTAL IRRIGATION COSTS		$888.67		
TOTAL PREHARVEST (GROWING) COSTS			**$3.16 /pkg**	**$3 001.11**

POSTHARVEST COSTS		Cost	$ /carton	$ /ha
Harvesting and packing costs				
Harvesting (6 row)	20 t/hr	$20.00 /t	$0.28	$266.00
18 L styro package	950 pkgs	$1.30 /pkg	$1.30	$1 235.00
Labour: packing (15 pkgs /hr)	950 pkgs	$14.50 /hr	$0.97	$918.33
Cooling	950 pkgs	$0.35 /pkg	$0.35	$332.50
Machinery - packing	950 pkgs		$0.20	$190.00
Cartage on farm	950 pkgs		$0.15	$142.50
TOTAL HARVESTING AND PACKING COSTS			$3.25	$3 084.33
Marketing costs				
Freight (to Brisbane, $25/pallet space)			$1.40	
Commission, levies	12.5%		$1.38	
TOTAL MARKETING COSTS	950 pkgs		$2.78	$2 641.00
TOTAL POSTHARVEST COSTS (harvesting + packing + marketing)			**$6.03**	**$5 725.33**

SUMMARY TABLE

	$/package (loose)	$/ha
TOTAL PREHARVEST COSTS	$3.16	$3 001.11
TOTAL HARVEST & PACKING COSTS	$3.25	$3 084.33
TOTAL MARKETING COSTS	$2.78	$2 641.00
TOTAL VARIABLE COSTS	**$9.19**	**$8 726.44**

Gross margin = Total income less total variable costs

	$/package (loose)	$/ha
Total income (950 packages/ha)	**$11.00**	**$10 450.00**
Less		
Total variable costs	$9.19	$8 726.44
GROSS MARGIN	**$1.81**	**$1 723.56**

BREAK-EVEN YIELD at $11.00 per 18 L package	603 packages /ha
BREAK-EVEN MARKET PRICE per 18 L package (950 packages/ha)	$8.92 per package
BREAK-EVEN ON FARM PRICE per 18 L package (950 packages/ha)	$6.41 per package
GROSS MARGIN per MEGALITRE of IRRIGATION WATER	$431 per ML

Actual gross margin when price or yield changes

Yield packages /ha	Price per package					
	$8.00	**$9.50**	**$11.00**	**$12.50**	**$14.00**	**$15.50**
750	– $1 236	– $254	$729	$1 719	$2 701	$3 684
850	– $1 001	$113	$1 226	$2 348	$3 462	$4 575
950	– $765	$479	$1 724	$2 978	$4 222	$5 467
1 050	– $530	$845	$2 221	$3 607	$4 982	$6 358
1 150	– $295	$1 212	$2 718	$4 236	$5 743	$7 249
1 250	– $59	$1 578	$3 216	$4 866	$6 503	$8 141
1 350	$176	$1 944	$3 713	$5 495	$7 263	$9 032
1 450	$411	$2 311	$4 210	$6 124	$8 024	$9 923

Enterprise characteristics

Growing risk	Medium
Price fluctuations	Medium to high
Working capital requirement	Medium
Harvest timeliness	High
Management skills	Medium
Quality premium	Sometimes
Spray requirements	Moderate to high
Labour requirements—growing	Low
Labour requirements—harvesting & packing	Medium

Last update: July 2002

A gross margin for processing sweet corn in New South Wales

Enterprise unit: 1 ha of centre pivot irrigated sweet corn

INCOME	Amount		$ /t	Total $ /ha
Yield (tonnes per hectare)	17 t/ha			
Price			$159.00	
TOTAL INCOME				**$2 703.00**

VARIABLE COSTS	/ha	$/unit	$/ha	Total $/ha
Seed				
Sweet corn seed	12 kg/ha	$18 /kg	$216.00	
TOTAL SEED COSTS				$216.00
Tractor costs				
Large equipment including labour, fuel, oil etc.				
Cultivation	2 x 0.7 hrs	$30.50 /hr	$42.70	
Lister	1 x 0.5 hrs	$30.50 /hr	$15.25	
Drill fertiliser	1 x 0.5 hrs	$30.50 /hr	$15.25	
Bedform	2 x 0.5 hrs	$30.50 /hr	$30.50	
Sidedress	1 x 0.5 hrs	$30.50 /hr	$15.25	
Interrow cultivation	1 x 0.5 hrs	$30.50 /hr	$15.25	
Boom spray	1 x 0.2 hrs	$30.50 /hr	$6.10	
Sowing	1 x 0.5 hrs	$30.50 /hr	$15.25	
TOTAL TRACTOR COSTS				$155.55
Irrigation				
Water	6 ML/ha	$17.36	$104.16	
Pumping costs	$22.93/ML	6 ML	$137.58	
TOTAL IRRIGATION COSTS				$241.74
Fertiliser				
Starter fertiliser (MAP)	200 kg	$0.48	$96.00	
Starter fertiliser (sulphate of potash)	100 kg	$0.66	$66.00	
Urea	380 kg	$0.42	$159.60	
Micro nutrients (foliar)	2 kg	$1.20	$2.40	
TOTAL FERTILISER COSTS				$324.00
Crop monitoring				
Crop scout			$60.00	
TOTAL CROP MONITORING				$60.00
Pest control				
Insecticide (at sowing)	2 L	$13.75	$27.50	
Insecticide (through pivot)	2.5 L	$81.00	$202.50	
TOTAL PEST CONTROL COSTS				$230.00
Weed control				
Herbicide 1 (pre-emergent)	3.2 L	$17.60	$56.32	
Herbicide 2 (pre-emergent)	0.5 L	$35.20	$17.60	
Herbicide 3	1 L	$24.70	$24.70	
TOTAL WEED CONTROL COSTS				$98.62
TOTAL PREHARVEST COSTS			**$77.99/tonne**	**$1 325.91/ha**

VARIABLE COSTS	$/unit	$/ha	Total $/ha
Harvest and postharvest costs			
Processors harvest and transport sweet corn	$0.00	$0.00	
National levy (0.5%)	$0.80	$13.52	
Freight (paid by processor)			
TOTAL FREIGHT HARVEST AND POSTHARVEST COSTS	$0.80	$13.52	$13.52

SUMMARY TABLE

	$/tonne	$/ha
TOTAL PREHARVEST COSTS	$77.99	$1 325.91
TOTAL POSTHARVEST COSTS	$0.80	$13.52
TOTAL VARIABLE COSTS	$78.79	$1 339.43

Gross margin = Total income less total variable costs

	$/tonne	$/ha
Total income (17 t/ha)	$159.00	$2 703.00
Less		
Total variable costs	$78.79	$1 339.43
GROSS MARGIN	**$80.21**	**$1 363.57**

BREAK-EVEN PRICE per TONNE	$78.79
BREAK-EVEN YIELD per HECTARE	8.42 t/ha
GROSS MARGIN per MEGALITRE of IRRIGATION WATER	$227

Actual gross margin when price or yield changes

Yield	Price per tonne					
t/ha	$139	$149	$159	$169	$179	$189
11	$195	$305	$414	$524	$633	$743
14	$610	$750	$889	$1 028	$1 168	$1 307
17	$1 025	$1 194	$1 364	$1 533	$1 702	$1 871
20	$1 440	$1 639	$1 838	$2 037	$2 236	$2 435
23	$1 855	$2 084	$2 313	$2 542	$2 771	$2 999

Last update: December 2003

Business management

When you become a sweet corn grower you are entering a new business, or at least adding a new enterprise to your business. Making this choice a business decision will help you keep the important issues in perspective. It means that thinking about and planning finance and marketing becomes as important as thinking about and planning production. No matter how good the product, the business will only be successful if you access profitable markets.

Operating a sweet corn enterprise as a business involves developing business and marketing plans, recording farm information, financial management, marketing and control (implementation of quality management systems). If growing sweet corn is an additional enterprise it should become part of your overall business plan, with its own marketing plan.

Business and market plans

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Government services
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To be successful all businesses need a plan. A plan helps you focus on your core business and what the business hopes to achieve. A business plan is generally drawn up for a five to ten year period and is a living document. It must be reviewed and modified annually to ensure objectives are met. Most financiers and investors want to see your business and marketing plans before they will lend you money.

To help you develop business and marketing plans you should talk to a Farm Financial Counsellor, a financial consultant, or undertake training provided under a government scheme such as those administered by FarmBis and Rural Adjustment Authorities.

The following outlines are a guide to the type of information you will need to develop plans that will help your business grow and prosper.

A typical business plan includes the following sections:

1. Mission
2. Situation analysis – SWOT (strengths, weaknesses, opportunities, threats)
3. Goals and objectives
4. Action plan/implementation
5. Budget
6. Control plan

As part of the business plan, marketing and financial plans may also need to be developed. A typical marketing plan includes the following sections:

1 Executive summary
2 Current marketing situation:
    - Domestic
    - Export
    - Competitive situation
3 Opportunity and issue analysis:
    - SWOT analysis (strengths, weaknesses, opportunities, threats)
    - A determination of what opportunities will overcome which threats, and which strengths can be used to overcome which weaknesses
    - Issue generation and prioritisation
4 Objectives:
    - Financial
    - Marketing
5 Marketing strategy:
    - Pricing
    - Product description and lines
    - Positioning and segments
    - Distribution strategy
    - Sales
    - Advertising and promotion strategy
    - Research and development
6 Action program and control
7 Budget

Record keeping

Record farm information

Accurate and ordered recording of farm information is essential for good business management. Types of information that should be recorded include:

- pre-harvest information (pest and disease monitoring records, spray program, labour inputs, leaf, sap and soil analysis, soil moisture monitoring, fertiliser and irrigation schedules);
- postharvest information (labour, harvesting, packouts, handling and storage logs);
- quality management records and financial details.

a key issue
Quality management
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Your quality management system will determine the type and extent of records you need to keep.

This information is best recorded on a computer where it can be quickly accessed and compared, but it can be recorded in books or on forms. A lot of this information is used to develop business and marketing plans and to check that plan objectives have been met. The information is also used to compare performance from year to year and in developing best farm practice.

Record financial information

Accurate recording of financial inputs and outputs ensures that the true financial situation of the business is known at all times. This is important for decision making. Accurate recording of inputs and outputs means recording all costs, including family labour, loan interest and depreciation.

There are several computer-based packages that will help you record financial information and keep an eye on your business.

a key issue
Gross margins
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Gross margin analyses for sweet corn production are provided as a guide in setting up your own financial recording program.

Marketing

The longer the marketing chain (the number of people between the grower and the consumer) the less control growers have over their produce and the lower their potential returns.

Growers have four ways of marketing their fresh market sweet corn.

Traditional marketing. This is the longest marketing chain. Growers send produce to an agent or merchant at a central market. They have very little control over their product once it leaves their farm. This is a low risk, low capital option.

Form strategic alliances with major suppliers/marketers. Growers supply product to an established marketing network that has established a customer base. This type of alliance is more able to offer a constant, regular supply. It is also a low risk, low capital option.

Join marketing groups or cooperatives and joint packing facilities. Growers market their produce through a group which may employ a marketing specialist. These groups are more able to offer a constant, regular supply and have enough volume to meet the needs of some larger customers. This option requires commitment and some increased investment but offers the potential for higher returns.

Sell direct to the major customers (retailers). This is the shortest marketing chain and gives growers the most control over their produce. Growers need to produce high volumes of produce for most of the year. Direct selling involves a large financial input, and growers must either have those marketing skills or employ a marketing specialist. This option is limited to a small number of large growers but has the best potential for higher returns.

Effective, targeted marketing will probably make the biggest difference to your success as a grower. Understanding what marketing is about provides you with a base on which to plan how best to produce your product.

Marketing is not:

- selling, or;
- expecting that someone else will look after your product, with your best interests in mind, once it leaves your property.

Marketing is:

- putting yourself in your customer's shoes and profitably meeting their needs within the limitations of your resources.

Successful marketing implies knowing who and where your customers are and what they want. It also implies knowing at what level of return you are making a profit. Sadly, Australian horticulture provides many examples of growers who do not know how or if their product is meeting customers' needs.

Your **customer** is the person paying you for your sweet corn, usually your agent, merchant or the retailer's buyer. The **consumer** is usually the person buying your sweet corn in the retail store and taking it home. Whilst it is fairly easy to find out your **customers'** needs, and if you are meeting them, it is much more difficult to find out the needs of the **consumer**.

If you have made a good choice of **customer**, it will be someone who has a good knowledge of the needs of the **consumer**, however unfortunately this is not always the case.

The financial performance of many horticultural businesses also indicates a lack of understanding about how cost of production is linked to marketing success. Many growers blame the 'marketing system' for poor financial results, which suggests that they think they are outside the marketing system. Nothing could be further from the truth.

The following suggestions may help you get onto the 'inside' of marketing.

Think as if you were a consumer

What does a sweet corn consumer look for, what is most important? Is it price, quality, size, colour, flavour, or a combination of these factors? If growers cannot reasonably guess at the answer to this question, how can they set targets for production?

For example, should you grow a yellow, bi-colour or white variety? Yellow varieties make up the bulk of the market, but does your wholesaler have a niche market for bi-colour or white varieties?

There is also a decision about how hard to grade out blemished cobs. Grading too hard means fewer cartons of very high quality (and higher price); grading too lightly means more cartons of lower quality (and lower price).

Another decision is at what point are market returns the best? How can a grower make these management decisions without knowing what consumers want and how much they are prepared to pay?

There are two important sources of knowledge and information about what the market wants:

- **Market research studies.** These are generally conducted by industry and research organisations and are published in special reports. Grower organisations and Horticulture Australia Limited are sources of this information.
- **Marketers who are in close contact with buyers and consumers.** For the domestic market, specialist sweet corn wholesalers in the major metropolitan markets are an invaluable source of detailed market knowledge. Market authorities in each of the major markets can provide some advice on sweet corn wholesalers. For the export market, sweet corn exporters are a source of expert market knowledge.

Know the marketing chain for your product

Knowing the marketing chain for your product means identifying all the steps and all the people that link your product at the farm gate to particular groups of consumers. One chain might include a transport company, an unloading company, a wholesale merchant, a supermarket buyer, a grocery section manager and consumers from a particular area of a city. Knowing how the chain works is important because you choose some of its players, and each of the players in the chain make decisions about your product that collectively influence its marketing performance.

Visit the markets where your product is sold

There is no substitute for seeing how your product is performing in wholesale and retail markets. But just looking at your product is not enough. You should be monitoring the product's physical and financial performance, and also assessing the performance of the people in your marketing chain. Remember that they are working for you but they will ignore this if you do not show interest in them.

Actively seek market information

Apart from visiting the markets you should actively seek information about each consignment. No news is not necessarily good news. Ask your agent to report on the acceptability of your product. Set up a fax, phone or e-mail system to receive this information quickly. Outturn inspection by independent assessors is also a useful way to get information about your product.

Join a marketing group (where available)

Small growers alone have little clout in the market and also miss out on sharing information with other growers. If you're considering marketing on your own so that you can closely guard information that you don't want others to have, think again. Chances are that while you're busily guarding your information, the rest of the industry will pass you by because no one will want to share their information with you. Joining a marketing group of like-minded growers is a positive step towards overcoming the dual problem of lack of marketing clout and lack of information.

Control (quality management)

All business and marketing plans need a control process to monitor, evaluate and modify these plans. Quality management systems fulfil this role. They are a method of developing a flow chart of the business with a series of checks for critical operations to ensure that they are done correctly.

Quality is built into every aspect of management

Quality is described as the fitness for purpose of a product. It implies a predictable degree of uniformity and dependability. But quality goes beyond just the product—it also includes services such as packing true to label and delivering on time. In short, quality includes all those things needed to satisfy your customers.

Quality management is the way you run your business to satisfy customers. Therefore growers are constantly engaged in quality management, perhaps even without being totally aware of it.

In the past, the suitability of the product for its intended market was determined by what is called 'end point inspection'—inspection at the market level. This system has a number of important flaws. It is:

- expensive to reject product at this late point in its cycle;
- difficult to predict product performance during the rest of the marketing process when its past history is unknown;
- often driven more by tradition than by the real needs of consumers.

Modern quality management aims to build quality right through the production and marketing process minimising the need for rejections late in the marketing chain. This system also provides consumers with documented evidence that the product they are buying will meet their needs. Think of quality management, as a marketing tool to achieve better prices and repeat sales, and a tool to identify areas for improvement, prevent mistakes and reduce wastage. It will also help you access markets with quarantine and other barriers to normal entry and promotes greater trust and cooperation between growers.

There are five core principles of quality management:

- The customer defines quality, not the grower.
- Quality management has to be planned, organised and managed; it does not happen by itself.
- Problems are identified at the earliest possible point, not at the end point.
- Decisions are based on facts, not feelings.
- Quality management is the responsibility of everyone in the business, including the workers—not just management or business owners.

It is not easy to put a quality management system together. You will need commitment, good planning, staff involvement, and simple and effective procedures including well-defined and objective quality standards.

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Quality management
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Formal quality management systems are recommended because they remove the guesswork and are widely accepted throughout industry.

Quality management

Quality management is a vital step in sweet corn production. How well you manage this will have a big effect on whether you make a profit or loss from your sweet corn enterprise. The quality of your product depends largely on your management, quality continually declines the further the sweet corn travels through the marketing system. Taking extreme care to avoid damage during harvesting, packaging and palletising is an essential first step to putting a top quality product on the market.

Quality management for sweet corn

Sweet corn growers are implementing quality management systems driven by both customer demand and food safety legislation.

Customer demand

Consumers are becoming more demanding. They want sweet corn to be attractive, consistently acceptable in quality, nutritious and safe to eat and they want convenience when buying. Their concerns about food safety have been heightened by outbreaks of food poisoning in other industries.

These consumer pressures have caused customers (retailers, processors, exporters and wholesalers) to be more demanding for quality and safety. For example, retail chains are increasingly requiring their suppliers to demonstrate that they have effective quality management systems in place. In other words, retailers want evidence that their suppliers can produce food that is safe to eat and will meet their quality requirements.

Most of the major retail chains in Australia are currently placing this requirement on direct grower suppliers and wholesalers. To meet these requirements, the wholesalers need to ensure that their grower suppliers have systems in place that will produce safe food of acceptable quality. Many of the food safety issues (particularly chemicals applied to produce) happen on-farm.

Processors and fast-food chains also require their fruit and vegetable suppliers to have quality management systems in place to ensure safe food is supplied.

Food safety legislation

Australia now has national arrangements for safe and hygienic production, storage, transportation and retailing of food.

Food businesses from primary producers through to retailers will have to meet the requirements of these new standards. The standards are risk-based, meaning that businesses with higher food safety risks will have to take more precautions when developing their quality management systems than some other food businesses.

Product specifications

The first step in developing a management system is a product specification that clearly defines the quality and safety features of the product. Many customers, for example Woolworths, have developed product specifications for their suppliers. Growers are also developing product specifications in consultation with customers. A sample product specification is shown in Table 38.

Product specifications normally include:

1. General description—product type, customers, intended use.
2. Quality description—colour, maturity, size, shape.
3. Quality defects—both major (make the product unsound) and minor (detract from the appearance of the product).
4. Consignment requirements—packaging, palletising, labelling, temperature, transport.
5. Food safety—contaminants (physical, chemical and microbial).

Product identification and traceability

The ability to clearly identify and do a trace back on products is an important part of product specification and quality assurance.

Product identification and traceability is the method used to trace product from its point of origin in the field, through the packing shed to the customer. It also enables trace back from the customer to the product's point of origin. A traceability code could be a 'packed on' date, but many packers prefer a code that only they can interpret. Letters of the alphabet can be printed on the package and circled for different days, blocks, etc. This gives the grower the ability to trace back from individual packages to the field. Computer-aided equipment that prints a code on each package is also available.

Table 38. A sample sweet corn product specification

1. General description	
Appearance	Kernels should be shiny, plump and well coloured with milky juice. The silks should still be attached to the cob. Flag leaves removed and remaining husk should fit closely to the cob and not be wilted. Cobs must be free from foreign matter.
Customers	Wholesalers and retailers in all Australian markets.
Intended use	Fresh produce for human consumption.
2. Quality description	
Colour	Golden yellow kernels. Green husk. Cream to brown silks.
Maturity	High moisture content in kernels, not shrivelled or dimpled, well coloured.
Size	Minimum cob length 180 mm.
Shape	Cylindrical to conical.
3. Quality defects	
Major defects:	
Pest damage	Evidence of: live insects or insect infestation; fungal or bacterial rots; virus symptoms.
Physical damage	Unhealed cuts, holes or splits.
Skin marks	Deep seated bruises or crushed areas on the kernels or cobs.
Temperature injury	Freezing damage (dark water soaked areas), or dehydration (shrivelling) of kernels.
Physiological disorders	More than 15% unfilled kernels (poor pollination) at the cob end.
Minor defects:	
Pest damage	Rust extending over more than 20 cm^2 of the husk.
Physical damage	Husk must not be penetrated in more than one place.
Skin marks or blemishes	Husk discolouration no more than 20 cm^2 caused by, for example, frost or spray burn.
Physiological disorders	More than 5% of consignment at wrong maturity, for example watery not milky juice (immature) or dry doughy kernels (over mature).
Stems/shanks	Shank length not more than 2 cm from the last husk.
Defect tolerance	
Major defects	Must not exceed 5% of consignment.
Minor defects	Must not exceed 10% of consignment.
Major + minor defects	Must not exceed 10% of consignment.

Quality specifications reviewable depending on seasonal conditions and specific customer requirements.

4. Consignment requirements	
Packaging/palletising	18 L polystyrene package. Pallets 8 cartons per layer x 9 or 10 layers high, preferably unitised for size.
Labelling	Cartons clearly marked with grower name, address, count or net weight and traceability code (for example packed on date).
Pulp temperature	0° to 4°C at receival unless otherwise negotiated.
Transport	Refrigerated transport unless otherwise negotiated.
5. Food safety	
Contaminants	Free of contaminants. Below Maximum Residue Limits (MRL's) for chemicals and below Maximum Permissible Concentration (MPC) for metals as specified in the Australian Food Standards code A12 – A14.

What level of quality management do you need?

The four broad levels of quality management practices being requested by customers are:

- Approved Supplier Program – not 3rd party audited;
- Approved Supplier Program – 3rd party audited;
- Hazard Analysis and Critical Control Point (HACCP) Plan;
- HACCP-based quality management standard or code.

The level of quality management you need to implement will depend on the marketing arrangements and the potential risk of the product causing a food safety problem.

Approved Supplier Programs not 3rd party audited

An Approved Supplier Program is required when growers who supply packhouses, marketing groups, wholesalers, exporters or processors must meet specific requirements to be an approved supplier to these customers. However, growers may not need to have a certified quality system to meet these requirements.

Approved supplier requirements may include:

- following agreed procedures for critical operations;
- keeping quality and safety records such as a spray diary;
- picking and packing to agreed quality standards;
- implementing a food safety plan.

The customer (or an independent company on behalf of the customer) conducts audits to check that the grower meets the approved supplier requirements.

Approved Supplier Programs 3rd party audited

The most commonly used of these programs is Freshcare.

Freshcare

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The fruit and vegetable industry has developed an on-farm food safety program called Freshcare. Wholesalers, processors, packers and marketing groups may use Freshcare as a minimum requirement for their approved supplier program. Certification to Freshcare is achieved through an independent on farm audit for compliance with the Freshcare Code of Practice. It is accepted by the three major retailers.

HACCP plans

HACCP is an internationally recognised method used to identify, evaluate and control hazards (things that can go wrong) to food products. HACCP was originally developed to provide assurance that food was safe to eat but it is now being used to ensure that customer quality requirements are met. It is being requested of some growers who supply products that are perceived to have a high risk of causing food safety problems or where the next business in the supply chain demands it.

HACCP relies on prevention to control potential problems. Potential hazards are assessed for significance and control measures are established to eliminate, prevent or reduce the hazard to an acceptable level.

Typical food safety hazards include excessive chemical residues, microbes causing sickness, and physical contaminants (glass, sticks) that may lodge in product. Some independent auditing companies will certify HACCP plans according to the Codex Alimentarius Commission guidelines.

HACCP-based quality management standard or code

The quality management standards or codes incorporating HACCP that are relevant to the horticultural industry are:

- ISO 9002 plus HACCP
- SQF 2000^{CM}, SQF 1000^{CM}
- HACCP 9000
- Supermarket quality management standards.

HACCP-based quality management standards or codes are required where growers or packhouses directly supply supermarket chains or where the next business in the supply chain demands this requirement. Check with each supermarket to see what standards or codes they will accept.

For SQF 2000^{CM}, SQF 1000^{CM}, ISO 9002 and HACCP 9000, an accredited independent company conducts audits to certify that the business meets the quality system standard.

For supermarket quality management standards, auditing is done by the supermarket or an independent company on their behalf.

ISO 9002

ISO 9002 is the international standard for quality management systems and the system on which most others are based. It was developed originally for manufacturing companies and is now used by many industries. It consists of 20 elements covering all aspects of producing products and servicing customers. Supermarkets require their direct suppliers to include HACCP in their ISO 9002 systems.

SQF 2000^{CM} and SQF 1000^{CM} Quality Code

The SQF 2000^{CM} and SQF 1000^{CM} quality codes were developed by AGWEST Trade and Development, Western Australia, specifically for small businesses in the food industry. They are recognised in Australia and in some Asian countries. The codes have specific requirements that must be addressed to achieve certification. The SQF 2000^{CM} audit code includes HACCP and requires a HACCP plan to be developed, validated and verified by a HACCP practitioner. The SQF 1000^{CM} quality code is based on HACCP and requires a food safety plan to be prepared from a master industry HACCP plan that has been verified by a HACCP practitioner.

HACCP 9000

HACCP 9000 is a quality management standard incorporating ISO 9002 and HACCP.

Supermarket quality management standards

An example of supermarket quality standards is the Woolworths Quality Assurance Standard developed by Woolworths Australia for their direct suppliers. It is aimed at food safety and quality requirements and is an HACCP-based quality management standard.

Other certification schemes

AQIS Certification Assurance (CA)

Certification Assurance is a scheme established by the Australian Quarantine and Inspection Service (AQIS) as an alternative to end-point inspection. It is a voluntary arrangement between AQIS and an exporting business. The CA system takes over the inspection function of AQIS, which now monitors the effectiveness of the CA system by a regular program of audits.

Interstate Certification Assurance (ICA)

Interstate Certification Assurance has been developed by Australian state departments of agriculture as an alternative to product inspection. It consists of a series of operational procedures that growers must follow to meet interstate quarantine requirements. Businesses are audited at least once a year.

What is quality management going to cost?

There is no simple answer to this question. Costs will depend on:

- size and complexity of the business;
- what level of quality management is wanted;
- how much knowledge the owner and staff have to develop and implement a system;
- whether outside help is needed.

Types of costs include:

- owner's time (this is the biggest cost);
- staff time involved in developing and implementing quality management;
- for large businesses, staff positions dedicated to quality management (monitoring, documentation);
- materials such as manuals, folders, posters, measuring equipment;
- training costs for owners and staff;
- consultant fees if outside help is needed;
- auditing costs if aiming for accreditation.

Quality management is an investment

There is a pay-off for quality management. As one grower has said, "An effective system does not cost, it pays". Like buying machinery, the time and money spent on quality management is an investment for future profitability.

Environmental management

Farmers are under increasing pressure to demonstrate their environmental credentials to the wider community. Farmers also need to ensure that they comply with a range of state and federal environmental legislation. One way of dealing with these issues is to make a start towards implementing an environmental management system or to at least check that your business is operating within your industry's Code of Practice and following environmental best practice guidelines.

Environmental Management Systems (EMS)

An Environmental Management System (EMS) is a systematic approach to managing the impacts a business has on the environment. An EMS does not dictate levels of environmental performance, however a minimum requirement is that it enables a business to comply with legislative requirements concerning the environment. It should also build on existing activities such as industry best management practices, industry codes of practice, quality assurance and food safety schemes and workplace, health and safety considerations.

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An EMS is not a product you buy off the shelf but a process that helps you to improve your business's environmental performance. This process has a number of steps:

- an environmental risk analysis to identify, assess and prioritise potential environmental impacts;
- setting environmental objectives and targets;
- developing an environmental management program to meet these objectives and targets;
- monitoring, measuring and recording environmental performance to check that objectives and targets are being met;
- reviewing the system at regular intervals and improving the system as needed.

The EMS process is based on the 'plan, do, check, review' management cycle to continuously improve the environmental performance of a business (Figure 26).

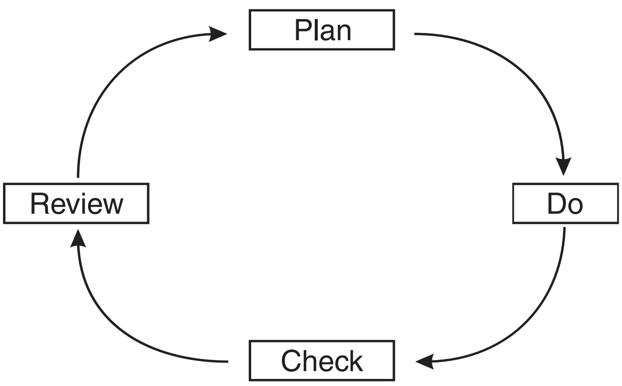

Figure 26. The plan, do, check, review cycle for continuous improvement

ISO 14001 is the most widely recognised auditable international EMS standard. It is a 'process standard', that is, it does not prescribe a particular level of environmental performance that a business must achieve other than the need to comply with all relevant legislation and industry codes of practice. As a process standard, ISO 14001 however does have quite stringent requirements as to the steps (processes) a business must take to implement ISO 14001 on their farm.

For more information about ISO 14001, contact Standards Australia at www.standards.com.au or your state office of Standards Australia.

The system must also be auditable by an accredited third party. In addition to the steps listed for implementing a general EMS, ISO 14001 has a number of additional components and features. Amongst these, it requires a business to have:

- an implemented, documented environmental management policy which is communicated to staff and available to the public;
- an implemented, documented environmental management system that includes staff training, communication, resourcing and responsibility aspects;
- procedures in place:
  - to meet legal and industry requirements;
  - for responding to accidents and emergency situations;
  - to take action to mitigate identified environmental impacts.

Protocols, codes of practice, best practice guidelines

Protocols, codes of practice and best practice guidelines differ from a process standard such as ISO 14001 in that they do prescribe a certain level of environmental performance that the business should strive to achieve.

A guide to EUREPGAP for Australian growers is available from the Department of Agriculture, Fisheries and Forestry on (02) 6272 3317, email: eurepgap@daff.gov or visit their website www.eurep.org

EUREPGAP for fruits and vegetables was started in 1997 as an initiative by European retailers, the Euro-Retailer Produce Working Group (EUREP). It is a protocol of good agricultural practice (the 'GAP' in EUREPGAP). Since then, it has been further developed by a European group of representatives from all stages in the fruit and vegetable sector with the support of producer organisations outside the European Union (EU). The EUREPGAP protocol lists requirements addressing quality, food safety, environmental management and workplace health and safety. Global support and interest in EUREPGAP has increased dramatically over the last three to four years. Currently there are a significant number of Australian horticultural export businesses working towards EUREPGAP in order to meet compliance deadlines stipulated by UK/European retailers and importers. In 2004, Woolworths accepted EUREPGAP as an acceptable Quality Assurance Certification (alongside HACCP, Freshcare, SQF) as outlined in their standard WQA.

Farmcare Code of Practice. Developed by Growcom to meet industry's legislative requirements and provide guidelines for growers, Farmcare is designed to assist Queensland's fruit and vegetable growers to meet their general environmental duty of care under the Environmental Protection Act 1994. The Farmcare Code of Practice for fruit and vegetables was developed under the umbrella of the Queensland Farmers Federation (QFF) Environmental Code of Practice. Farmcare has no certification capability and cannot be externally audited.

more info

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Farmcare outlines a range of potential environmental harms and management options for minimising impacts from those harms. The code is split into seven sections:

- Land and soil management
- Water management
- Biodiversity management
- Air management
- Noise management
- Waste management
- Integrated crop management

Enviroveg is a relatively new program initiated by the Australian Vegetable and Potato Growers Federation (AUSVEG). Enviroveg is committed to encouraging vegetable growers throughout Australia to adopt and implement good environmental management practices. The Enviroveg manual is divided into eight sections that address the different aspects of managing a businesses's environmental impacts. Each section lists specific environmental best practices, provides a scoring system and back up information. The program also includes training and review components and a self-assessment checklist. This checklist is designed to help growers compare their current farming practices with those listed as environmental best practice under the Enviroveg guidelines. At present, Enviroveg has no certification or third party auditing capability but this may change in the future.

more info

For further information:
www.enviroveg.org

A number of other EMSs, protocols and best practice guidelines will be, or already are, operating within Australia. There are moves at the national level to coordinate and clarify the role that these various environmental management programs will have in horticulture. These efforts are also targeted at better linking environmental management with existing QA, food safety and workplace, health and safety programs. We do not know if or when or what type of EMS will be required in the horticulture industry within the next few years. It will in part depend on the markets and customers you are aiming to supply. As a minimum, you should become familiar with Growcom's Code of Practice.

Farm safety

Recent statistics suggest that agriculture is the second most dangerous industry in Australia, with on average, one death occurring on a farm every three days. As an employer and farm business manager, you are responsible for ensuring that your staff, family and yourself are working in a safe environment. This responsibility not only rests on your concern for people and their well-being but also makes sound business sense.

This article is largely based on information from the Australian Centre for Agricultural Health and Safety at the University of Sydney and Farmsafe Queensland.

The farm as a workplace

Australian agriculture is traditionally viewed as an industry where people work and live in the country, enjoying wide-open spaces, fresh air, good health and a lifestyle relatively free from outside interference. The reality of life on the farm is somewhat different. Australian agriculture has one of the highest rates of workplace accidents, and farmers, unpaid family members and farm workers are in one of the highest risk groups for occupational injury and disease.

According to the Australian Centre for Agricultural Health and Safety, tractor accidents remain the main cause of serious and fatal injuries, but vehicles, motorbikes, particularly four wheeled ATV's, mobile plant and post-hole diggers also cause their share of serious and fatal accidents. In addition to the high number of fatalities occurring on farms, estimates indicate that between 200 and 600 injuries per 1000 farms require attention at rural hospitals each year. Farmsafe Queensland reports that manual handling injuries are common particularly those causing musculoskeletal injury. In 2000-2001, the fruit and vegetable industry accounted for 25% of the total compensation paid in the rural industry (Source: Qstats, Queensland Government 2001).

These statistics however only represent the tip of the iceberg, with many injuries, including cuts, fractures and back injuries, not reported to hospitals, workers compensation sources or insurance providers and so not appearing in official statistics. Not only do farm accidents cause pain and suffering, they usually represent a major financial burden to the farming business. Costs include delays in getting work done, payment for medical treatments and rehabilitation, wages for replacement workers and high workers compensation, personal accident and disability premiums.

Your workplace health and safety obligations

Until recently, agriculture has lagged behind other major industries when it comes to improving its occupational health and safety performance. According to the Australian Centre for Agricultural Health and Safety, there are a number of reasons for this:

- farmers often carry out a range of different task under different conditions in the course of a typical working day, and between seasons;
- farm work is often undertaken in physical isolation;
- farm workplaces and work processes are often difficult to control, for example the weather;
- farm work is often carried out under pressure, when seasonal or weather conditions demand that jobs are completed on time to avoid gaps in planting or downgrading in product and price;
- farm businesses rely on a seasonal workforce particularly at harvest and hours worked during peak season are often long and physically demanding;
- farm safety risks and solutions are not well-defined and legislation may be difficult to interpret and apply in practical terms on farm;
- lack of relevant information, tools, education and training in managing farm occupational health and safety risks;
- attitudes, values and perceptions of risk;
- lack of financial incentives and the high cost of addressing farm occupational health and safety risks by small business owners;
- the family home is often located on the farm which places children and visitors at risk.

more info

Safe storage, use and disposal of pesticides
This chapter page 230

Over the past two to three years, this situation has changed rapidly and there is now some urgency amongst horticultural industries to address workplace health and safety issues. Prosecutions under the Workplace Health and Safety Act, Electrical Safety Act and the Dangerous Goods Safety Management Act are adding a significant cost to farm production. There have also been an unprecedented number of successful civil action claims brought against corporate farms and individual producers in recent years. Added to this, the size of horticultural businesses is increasing with some larger enterprises employing not 10 or 20 staff, but hundreds of staff during peak season.

The biggest potential cost to farm businesses is the cost of doing nothing. Contemporary occupational health and safety legislation requires that employers' managers implement a risk management approach to health and safety requirements on farm. The underlying principles of risk management relate to:

- identifying hazards;
- assessing risks;
- controlling risks.

This approach has some similarities with the Hazard and Critical Control Points (HACCP) approach for identifying food safety and quality risks within Quality Assurance systems. Many horticultural businesses have already implemented some form of QA so the risk management approach to occupational health and safety is not a new concept for most vegetable growers.

The Managing Farm Safety program

Your obligations as an employer and farm manager are based on three principles:

- A concern for people and their well-being—people have a right to go home in no worse condition than when they came to work.
- It makes good business sense—people are your most valuable resource. Injury and illness costs time and money and impacts on your profitability.
- To meet statute and common law obligations.

To discharge your common law obligations you must provide:

- a safe place of work;
- safe systems of work;
- safe plant and machinery;
- competent and trained staff.

Under common law, an employer is judged by 'the four tests':

1. Foreseeability—is there a risk? Can it be foreseen?
2. Prevention—is there a reasonably practicable method of preventing the risk?
3. Causation—was the injury caused by an agent of injury to which the employer had prior knowledge?
4. Reasonableness—failure to eliminate risks shows a lack of reasonable care.

The best way to meet your workplace health and safety obligations is to take part in the **Managing Farm Safety** program developed by Farmsafe Australia. The Managing Farm Safety program is aimed at developing skills in risk management of farm safety—an approach that is consistent with the way other farm business risks are managed.

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Farmsafe offers a complete package of information, training and systems that allows a primary producer to manage farm safety in their workplace. The training course and resource package are based on real data about the major risks on Australian farms, including specific agricultural industries, and takes into account the requirements of current occupational health and safety legislation.

References

Links to Rural Code of Practice:
www.whs.qld.gov.au/subject/rural.htm#codes

Link to Rural Safety Links:
Web: www.whs.qld.gov.au/subject/rural.htm#links

Farmsafe Australia website—document from Australian Centre for Agricultural Health and Safety, The University of Sydney—Managing Farm Safety, Difficulties and Solutions:
www.farmsafe.org.au/mfs.htm

Understanding the sweet corn plant

An understanding of the plant will help you understand the conditions and treatments necessary to produce sweet corn economically. The following sections are based to a large degree on information gathered from the references listed on page 129.

Introduction

There are two main differences between sweet corn and other corn types. Firstly is the presence of a gene or genes in sweet corn that affect starch production in the endosperm (the main storage organ of the kernel), and secondly is its use as a fresh market and processed vegetable. Sweet corn is harvested when the kernels are immature so that sweetness and tenderness are optimum for consumption. Sweet corn is highly perishable because the ear is physiologically immature when harvested.

Evidence suggests corn is native to central America. Sweet corn arose from a mutation known as the su_1 or sugary gene (often referred to as the su gene), in a Peruvian race of field corn. This gene gives a normal or standard sweet corn its characteristic sweetness and creamy texture by increasing the concentration of sucrose and phytoglycogen (a water-soluble polysaccharide) at harvest maturity.

By 1900, 63 sweet corn varieties were being grown in the USA, and in 1902 *Golden Bantam*, an open pollinated variety, was introduced marking the beginning of a trend for yellow kernel types (earlier varieties were white). In 1924, the first sweet corn hybrid, *Redgreen*, was released and by 1947, 75% of sweet corn varieties grown were hybrids. Now almost all sweet corn varieties are single cross hybrids.

It took some time after the discovery of the supersweet gene (sh_2 or shrunken-2) in the late 1940s until a hybrid supersweet with commercially acceptable seed quality and vigour was developed. The first, *Illini Xtra Sweet*, was released in 1961. *Florida Staysweet* was released in 1978 and became the mainstay of the Florida, USA industry and aided in developing markets in Taiwan and Thailand. This variety was grown commercially in north Queensland until recently as an early season start-up variety.

Development of supersweet (sh_2) varieties was relatively slow until the early-mid 1980s when seed companies with sweet corn breeding programs realized the market importance of sh_2 varieties and began active breeding programs. Until then the sweet corn varieties marketed were mostly the normal or standard (su_1) hybrids. Today, almost all new fresh market varieties and an increasing proportion of processing varieties are sh_2 types.

The other fresh market corn sold in retail outlets is baby corn. Baby corn is the unpollinated, immature cob of any corn (*Zea mays*) genotype (Kotch et al 1995). Cobs are picked by hand at the correct stage of maturity, just as the silks emerge from the cob, and this can stimulate the development of further cobs. The husk is stripped and the immature cob is packed on trays and covered with clear food wrap. It is mainly used in stir-fry cooking.

Virtually any corn cob type can be used but for commercial production, multiple cobbing types such as popcorn are normally grown. Popcorn varieties include Snobaby and Snopop, and up to five baby cobs could be harvested from one popcorn plant.

Different markets may have different preferences for cob size. Cob size is determined both genetically, by the size of the mature cob and by the stage of maturity.

Botany of the plant

Sweet corn, *Zea mays*, is a monocotyledon in the grass family, *Poaceae* (formerly *Gramineae*). It is a tender, warm season crop. The upright stalk is divided into segments (internodes), by the nodes. Roots, branches (tillers), leaves and ears all originate from the nodes. The male flowering part, the tassel, is at the tip of the stalk. Each ear, which contains the female flowers on a hard, thickened cob, is tightly wrapped in modified leaf sheaths called husks (see Chapter 3, page 26, Figure 6).

All normal corn plants follow the same general, orderly pattern of development from planting to maturity, but the time interval between stages and total leaf numbers produced may vary between different varieties, planting times, seasons and locations. For example, an early maturing hybrid may develop fewer leaves or progress through stages at a faster rate than the average, while a late maturing hybrid may develop more leaves than average and progress more slowly.

Temperature; environmental stress, for example, nutrient or moisture deficiencies; and general environmental conditions, may also affect:

- the rate of plant development;
- the relative time between vegetative stages and reproductive states;
- the length of the reproductive growth period;
- the number of kernels, their size and rate of weight increase.

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Crop Management Handy Guide on page 264

While growth is continuous, certain distinct events occur in each growth stage that do not happen in the others. Growers should be familiar with sweet corn's growth sequence so they can make the best management decisions at each growth stage.

Crop development

The development of sweet corn can be divided into five stages:
1. germination and emergence;
2. vegetative development;
3. tasselling and ear initiation;
4. pollination and silking;
5. kernel development and maturity.

1. Germination and emergence

The kernel contains enough stored energy to provide nutrients and food to the corn seedling until its roots and leaves can survive on their own. The mature sweet corn kernel has three main parts: pericarp, endosperm and embryo.

The **pericarp** is a protective layer of tissue derived from the ovary and surrounds the entire seed. It protects the seed before and after planting by limiting the entrance of fungi and bacteria.

The **endosperm** with a special outer layer (aleurone) accounts for most of the kernel and is the chief storage organ. In sweet corn it consists of sugar, starch and intermediate products. It supplies energy for the embryo during germination and emergence. The endosperm is smaller in supersweet corn than in other corn types so planting in conditions that allow quick germination and emergence is critical. The reduced storage volume gives supersweets the characteristic 'shrunken' kernel appearance.

The **embryo** consists of the scutellum and the embryo axis. The scutellum and aleurone produce enzymes that digest the endosperm during germination and seedling development. The embryo axis is actually a tiny corn plant in a dormant stage. It consists of a plumule (leafy part), in which leaves are already formed in miniature and a radicle (root like portion). Most corn varieties have five leaves in embryonic form in the seed in addition to the modified first leaf or scutellum.

When the seed is planted in warm, moist soil, it absorbs water through its tip. As water enters through the pericarp, the kernel swells and increases in weight. Growth begins in the embryo axis where the radicle and early seminal (primary or seed) roots burst through the pericarp at the basal end of the seed as it germinates. Soon the plumule, surrounded by a sheath called the coleoptile, emerges and grows in the opposite

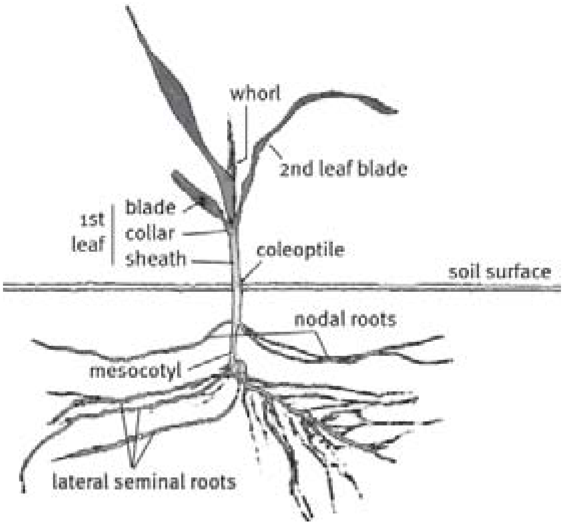

Figure 27. The parts of a seedling plant

Source: How a Corn Plant Develops, *Ritchie, S. W. et al., (1992)*

direction. Next, the radicle and subsequent roots anchor the young seedling and aid in water and nutrient uptake until the permanent root system is established later in the vegetative phase. With supersweet corn varieties, if the seed is planted too deep, or the soil is too cold or too dry, there is insufficient energy in the endosperm to achieve emergence, so the plant stand will be poor and uneven.

The seedling is brought to the surface by the mesocotyl (first internode) which is between the seed and the lowest node of the stalk. Elongation of the mesocotyl and coleoptile stops when the coleoptile tip is exposed to sunlight. Depending on soil moisture and temperature conditions, the coleoptile generally emerges from the soil around four to 14 days after sowing. The rapidly growing embryonic leaves then grow through the coleoptile tip and the above ground plant develops.

2. Vegetative development

After seedling establishment, vegetative development of the leaf structure and root system begins.

Leaves

The leaves are first to emerge from the soil after the coleoptile and are the only above-ground plant organs until internode expansion begins when around six to ten leaves are visible at the surface. These early leaves appear at about one every three days but never get very big. During this early growth stage, the growing point of the plant is below or near the soil surface and it is from there that the new large leaves are produced. The rate of new leaf initiation is therefore more affected by soil temperature than air temperature. For a typical sweet corn plant, initiation of all leaves, sheaths and nodes is almost complete before internode expansion begins.

As the internodes expand, the stalk rises through the tube formed by the leaf sheaths which developed earlier. The long, narrow leaves, eventually around 15 to 20 cm long depending on variety and environmental conditions, unfold one at a time, alternating between opposite sides of the stalk. Each leaf consists of a thin flat leaf blade with well-defined midrib and parallel veins, a sheath, and at their junction, a ligule, a small protuberance only a few millimetres long, the width of the leaf and approximately at right angles to it. The leaves manufacture food and evaporate surplus moisture.

The lowest leaves on the plant may die off due to very low light conditions in dense canopies. The upper leaves are sometimes damaged by wind and also may start to die off. The last leaves to die on corn plants grown to maturity are those nearest the node of the main ear.

Roots

Because the radicle and lateral seminal roots (collectively termed the seminal root system) begin growth directly from the seed, the soil depth at which they initially develop depends on the planting depth of the seed. Growth of these roots slows soon after emergence and is virtually non-existent by about the time the third leaf is visible; their main contribution is made before the permanent root system becomes established.

The permanent root system starts to develop as rings of roots emerging from the first four or five nodes of the stem which remain underground. Aerial brace (prop) roots often emerge from the lower two or three above ground nodes near the end of vegetative development.

The fibrous permanent roots freely branch outward and downward in an umbrella shape to support and nourish the young plant. The root system of a mature sweet corn plant rarely exceeds 1 m and often may be no deeper than 0.5 to 0.75 m.

Stalk

The corn stalk functions as a storage organ and support structure for the leaves and flowering parts. It differs from the stem of most grasses as it is filled with tissue, the pith, which adds structural strength. It stores nitrogen and considerable amounts of soluble solids, mainly as sucrose. Translocation of these during ear development contributes to filling the kernels.

Because internode expansion occurs late, during the period of rapid expansion, stalks are more affected than leaves by stresses or deficiencies that increase during vegetative development. These stress factors include shading, inadequate soil moisture, nutrient availability and high temperature.

Tillers

Axillary buds on the nodes at the base of leaves appear identical when initiated, but those at the upper nodes develop into the female reproductive structures (ears), while those at the lowest nodes can develop into secondary stalks or tillers in some varieties. Sweet corn varieties in general are less likely to tiller than many field corn types. The degree of tiller development varies with variety, fertility, environmental conditions and plant density. Higher plant populations can inhibit tiller development but may also reduce cob size.

Tillers (Figure 28) are generally considered undesirable because they rarely produce marketable ears, however there is no strong evidence that

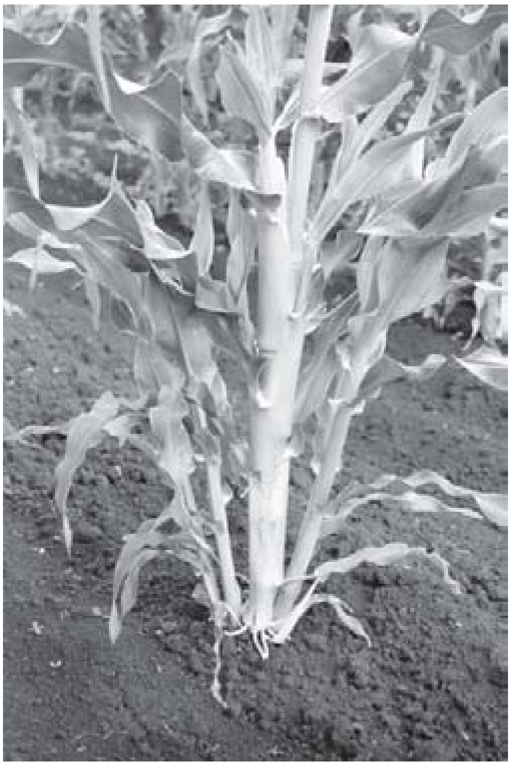

Figure 28. Tillers, left and right, and main stalk, centre

tillering does affect marketable ear production. Tillers are more likely to be a 'nuisance' factor, possibly interfering with the penetration of pesticide sprays.

3. Tasselling and ear initiation

At about when the fifth leaf has emerged, all leaf and ear shoot initiation stops. The growing point elongates and a microscopically small staminate (male) flower or tassel is initiated in the tip of the growing point. Leaf number on the main stem is therefore determined by when the flowering organs are initiated. At this stage the growing point is just under or at the soil surface, although total above-ground plant height is about 20 cm. Flooding at any time when the growing point is below the water level can kill the corn plant in a few days, especially in high temperatures.

By the time the sixth leaf has unfolded, elongation has carried the growing point and developing tassel above the soil surface and the period of rapid growth commences. The stalk unfolds like a telescope when it is lengthened and the permanent roots grow quickly throughout the soil in the rooting zone. The ear shoots develop from the axillary buds at nodes about half to two-thirds up from the plant base.

At around the appearance of the ninth leaf, the growing point of the ear shoots elongate to form the beginning of an ear. An ear shoot will develop from every above ground node, except the last six to eight nodes. Axillary buds at higher nodes are inhibited by the development of the tassel.

Initially, each ear shoot develops faster than the ear shoots originating above it on the stalk. However, growth of most lower stalk ear shoots eventually slows and only the upper one or two ear shoots ever develop into a harvestable ear. At this point the tassel begins to develop rapidly and stalk growth is rapid through internode elongation. Each internode commences elongation before the internode above it on the stalk, similar to the start of ear shoot development.

At about the time the tenth leaf has opened, the time between the appearance of new leaves shortens, generally to around two to three days. The sweet corn plant begins a rapid increase in dry matter accumulation which steadily continues well into the reproductive stages. Water supply and soil nutrients are in greatest demand during this increased growth rate.

When husk initials on the ear shoot have all formed, a period of more rapid elongation commences. Rows of two-lobed swellings form along

the ear. Each lobe produces a spikelet with two flowers, although one of these spikelets usually aborts in most varieties. Since one fertilized kernel results from each spikelet, the kernels on the mature ear appear in paired rows. Although the ear shoots were formed before tassel formation, the number of potential kernels on each ear and the size of the ear are determined from about the twelve leaf stage.

The most critical development period in terms of determining seed numbers on the ear starts after about the fifteenth to seventeenth leaf stage, around 10 to 12 days from the silking stage. **Water stress during the two weeks before and two weeks after silking will have a greater affect on seed yield than similar stress at any other growth stage.** This four week period around silking is the most important time for irrigation.

The male flowers develop within the whorl of uppermost leaves and the tip of the tassel (Figure 29) may be visible around the seventeenth leaf stage. At about the appearance of leaf eighteen, the aerial or prop roots are growing from the nodes above the soil surface. After the uppermost leaf opens the tassel finally emerges from the whorl. It may be less than 10 days to full development and pollen shed. At this time the tip of the ear shoot can also be seen. The number of rows of kernels per ear has already been established, but the number of kernels per row is not determined until about a week before silking.

Ear development continues rapidly about one week before silking and stress during this time delays ear and ovule development more than tassel development. Delayed ear development can cause a lag between the start of pollen shed and the start of silking. If the stress is severe enough silking may be delayed until pollen shed is partially or almost completely finished. The later silking ovules won't be fertilised resulting in incomplete seed set (blanks) on ears.

Figure 29. *Early tasselling (upper) and a fully expanded tassel (lower)*

4. Pollination and silking

When the last branch of the tassel is completely visible, and before the silks have emerged, the corn plant will almost attain its full height. This usually occurs about two to three days before silk emergence. Normally, the tassel can be seen several days before any silks appear from the husks (Figure 30).

The tassel often becomes fully spread prior to pollen shed (anthesis), Figure 31. Pollen dispersal is mainly by air movement and for each plant will last about seven to 10 days. Pollen shed usually occurs in the late mornings and early evenings.

A silk elongates from each flower and eventually extends out of the husk at the tip of the ear. Silk growth continues until fertilisation, basal spikelets develop first and silk emergence proceeds towards the tip. Although silks from further up the ear start elongating later, they may emerge sooner than basal silks because of the shorter distance travelled. The result is that the first embryos fertilised are often those near the middle of the ear. Silks from nearest the tip of the ear sometimes emerge too late to receive viable pollen, resulting in poor 'tip fill'. However, development of the ear shoot is usually in time with tassel development so that most of the silks emerge during pollen shed.

When the pollen grains fall, they are trapped by fine hairs on the moist, sticky silk, Figure 32. The grains germinate and a pollen tube grows down the silk channel to the female flower. It takes about 24 hours to reach the ovule, where it ruptures and fertilisation produces a new kernel. If silks are damaged before the pollen tube has fertilised the ovule, for example chewed by grubs, pollination may not occur and 'blanks' appear on the cob from these missing kernels.

The amount of pollen that lands on the silks, and the timing of this for any one plant, is likely to be insufficient for all kernels on the ear to be ferti- lised. To produce ears with complete kernel fill you need stands of several plants grown closely together. To achieve this commercial plant spacings usually range from 75 to 100 cm between rows and 20 to 30 cm between plants.

Figure 30. *Early silking*

Figure 31. *A fully expanded tassel and pollen*

5. Kernel development and maturity

Following fertilisation, rapid growth of the husks, cobs and young kernels occurs. Soon after pollination, the silks wilt, dry and turn brown. The ear shoot enlarges to become a mature ear wrapped in a husk. When the developing kernels are a watery blister the cob reaches full size.

As the kernels grow the plant is storing food in them and the constant increase in dry matter and loss of moisture concentrates sugars in the kernel. The 'milk' stage is reached when the kernels are plump, juicy, firm and contain a milky fluid high in sugars. The tip will be filled out and the husk tight. This normally occurs around two to three weeks after pollination. At this stage the ear is ready for harvest as fresh market sweet corn.

In normal or sugary (su_1) sweet corn, maximum sugar levels are usually reached between 16 and 20 days after pollination. After this sugar accumulation in the kernels decreases and starch increases. Within a week the sugar content may be down to half the maximum.

With the supersweet (sh_2) sweet corn types, high sugar levels are maintained throughout kernel development. Even 28 days after pollination, supersweet types have very high sugar levels with no increase in starch. Unlike in normal sugary sweet corn, factors determining the harvest period in supersweets are kernel moisture level and pericarp tenderness. As sweet corn matures, the kernels lose moisture and eventually begin to shrivel. This is not acceptable for fresh market sweet corn. The pericarp (outer layer of the kernel) also toughens with increasing days after pollination.

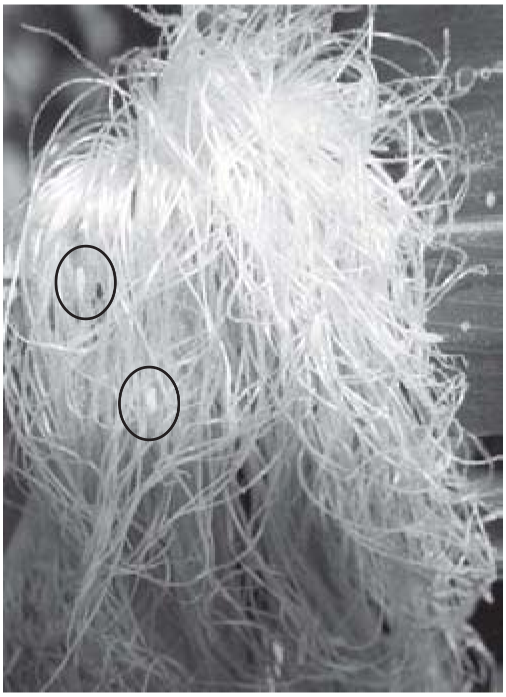

Figure 32. Pollen trapped on silks

Some supersweet hybrids will maintain quality longer than other types. Early maturing varieties of sweet corn pass through this best edible period faster than the later maturing varieties.

Types of sweet corn

There are several different types of sweet corn, based on sweetness and kernel colour.

Types of sweetness

In recent years there have been many developments in sweet corn, with newer varieties that have improved sweetness compared to standard or normal varieties. Sweetness in corn results from the accumulation of sucrose in the kernels, but at warm temperatures sugars are rapidly lost. Varieties now available have more sugar and retain sweetness longer.

Standard or normal sweet corn differs from field corn by a single gene called the sugary or su_1 gene (often written as su). The seed is more shrivelled than field corn but will geminate quite well in cooler soil conditions. The sweetness level is fair, often peaking around 5 to 11%, but the sugar is rapidly lost after harvest. These maximum levels last in the field for only two days at 27°C or 5 days at 15°C before sugar is converted to starch. Even when ears are harvested at maximum sugar content, the sugar content declines by 8% after storing for 24 hours at 0°C and by up to 52% at 30°C. This makes standard varieties difficult to get to consumers before sugar levels decline.

Supersweet sweet corn differs from normal sweet corn in having a gene that results in much sweeter sweet corn. Named the shrunken-2 (sh_2) gene, sweet corn varieties with this gene start out sweeter and lose sugar more slowly. Peak sugar levels of supersweet varieties can range from 22 to 40%. After two days at 27°C a supersweet hybrid has double the sugar content of a freshly harvested standard hybrid. Following storage at 4°C, sugar levels remain unchanged after four days.

As the name suggests, the seed is very shrunken and very poor germination can occur in cooler soil or under adverse conditions. The seed coat or pericarp of the kernels of these varieties can be fairly thick giving them a 'crunchy' characteristic. Isolation from other corn types is essential because cross pollination by any other corn type results in loss of sugar content and starchy, hard kernels. Despite these disadvantages, the very sweet flavour and extended shelf life give these varieties a unique marketing advantage.

While the sugary and supersweet types are the main sweet corn types marketed in Australia, there are a number of other genes that produce varying levels of endosperm sugar in sweet corn. Some of these have been used in developing commercial varieties overseas, particularly in the United States. The major gene is the **sugary enhancer**, denoted by the symbol se_1 which enhances the sugar level of normal or sugary corn. Varieties with this gene have sugar levels between the sugary and supersweet types. They tend to be grown for sale in roadside stalls in mainland USA and are used more for fresh market than the sugary types, but are well behind supersweets. Combinations of su_1, se_1 and sh_2 genes in hybrids have also been produced and have been termed 'Sweet Breed'.

Other genes used, almost exclusively in Hawaii, are the brittle-1 (bt_1) and brittle-2 (bt_2) genes, where varieties adapted to Hawaii and the tropics have been developed. Several other genes have been experimented with but are of minor consequence commercially.

Kernel colour

Within commercial sweet corn varieties, there are three main types of varieties: yellow, white and bi-colour (25% white and 75% yellow kernels on the same ear). Bi-colour hybrids are produced by crossing a yellow inbred with a white inbred. Most corn for processing is yellow. The popularity of the colour types varies between regions.

Isolation is required to produce pure white sweet corn. Because white is recessive to yellow, pollen from yellow or bi-colour varieties will produce some yellow kernels on the ears.

Effect of environment

Several environmental factors affect how sweet corn performs.

Light

The rate of plant development is primarily governed by temperature, but corn is also affected by daylength which has the potential to influence leaf number and the timing of flowering. Short days tend to reduce leaf number and shorten the time to tasselling and silking. However this generally doesn't affect most commercial varieties as they are not very sensitive to daylength within the climate range to which they are adapted.

However, when varieties are grown in environments to which they are not well adapted, they can become sensitive to daylength. This can occur when temperate varieties which are not particularly affected by the longer daylengths of higher latitudes, such as in southern Australia, are grown in northern Australia. The relatively shorter days of the tropics may reduce leaf number and promote earlier flowering.

Conversely, most tropical sweet corn varieties are unaffected until daylength exceeds 14.5 hours. This daylength is not encountered in most tropical areas, only at latitudes of 30° or higher. Some tropical varieties will not flower in a temperate area until the days shorten.

Corn is best adapted to high light conditions with a high photosynthetic capacity and requires full sunlight. Low light conditions due, for example, to extended cloudy weather or high planting density can adversely affect ear development, delay pollen shed and lead to barren plants. A major advantage of hybrid sweet corn varieties is the uniformity of plant growth rate and height, minimizing the chances of individual plants shading their neighbours. This lack of dominance should reduce the chances of producing barren plants.

Temperature

Sweet corn thrives in warm conditions and produces best under a long growing season. The plants require a warm climate and are sensitive to temperature extremes. Light frosts can injure or kill them. However, sweet corn has an advantage compared to many chilling sensitive species in that the growing point remains below ground for the first few weeks of development and is less prone to damage from light frosts.

Photosynthesis is determined by daytime temperatures, whereas development and respiration are determined by both day and night temperatures. The optimum growing environment for maximum production is one with warm days and relatively cool nights. Cool nights are important near harvest to slow maturity rates of kernels and maintain high sugar content and tender pericarp. Optimum daytime temperature for maximum productivity is 24 to 30°C and average night temperatures around 13°C. Growth ceases below 10°C while temperatures above 35°C are usually above the optimum for photosynthesis and can be detrimental to development of reproductive parts and reduce ear quality.

Soil temperature above 14°C is essential for germination of supersweet varieties and temperatures above 18°C are necessary for good germination. Normal sweet corn will germinate at soil temperatures above 12°C. Cool or wet conditions will slow germination and increase the chances of seed rots, poor emergence and uneven plant stands. However, there is variation in optimum temperatures among sweet corn varieties, particularly with respect to soil temperatures for germination and air temperatures during the ear maturation phase.

Water and nutrients

Sweet corn is not tolerant of drought conditions despite having a relatively high water use efficiency. Reasons for this include a relatively shallow root system and the sensitivity of its reproductive processes and ear quality to water stress. Short periods of drought during flowering may slow silk elongation and accelerate or delay pollen being shed. This can adversely affect the timing of pollen shed in relation to silk receptivity for fertilisation to occur, resulting in poor ear fill or incomplete development of kernels throughout the ear. Drought can also cause poor husk cover leading to insect or bird damage on exposed ear tips.

While only relatively small amounts of nutrients are required in the very early growth stages, high concentrations of nutrients in the root zone during these early stages benefit early plant growth. During this period the various plant parts are being initiated and start to grow. While the quantity of nutrients taken up is relatively small, the final size of the various plant parts such as leaves and ear is dependent upon having adequate nutrients available during the early growth stages. Since the seminal (seed) root system acts as the main root system during the first few weeks after plant emergence (it is elongating as the plant emerges from the soil), an adequate supply of fertiliser is required close to the germinating seed for the seminal roots to intercept it.

As the nodal roots start to develop above the coleoptile at emergence, they become the main root system of the corn plant some two to three weeks later. This nodal root system proliferates throughout the soil so precise placement of nutrients is less critical once these roots have developed. This also coincides with the plants' requirement for larger amounts of fertiliser during the later growth stages.

Uptake of potassium is completed soon after silking, but uptake of other nutrients such as nitrogen and phosphorus continues until near maturity. Much of the nitrogen and phosphorus and some other nutrients are translocated from vegetative plant parts to the developing kernels later in the season. This can result in nutrient deficiencies in the leaves unless nutrient levels are maintained during this period. While much of the nitrogen and phosphorus are removed in the cob at harvest, most of the potassium taken up remains in leaves, stalks and other plant residues and can be returned to the soil.

Optimum pH for availability of nutrients for sweet corn is 6.0 to 6.5. While this crop does not have a high requirement for trace elements, on light sandy soils and at certain pH levels, boron, zinc, magnesium or manganese may be inadequate for normal growth.

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Production systems for various markets

There are five distinct markets for sweet corn, fresh market, processing and export sweet corn, plus organically grown sweet corn and baby corn. The production system varies in some aspect for each different market.

Fresh market—domestic and export

Agents sell your produce on your behalf, then receive a commission, usually about 12.5%. **Merchants** buy the produce from you at an agreed price, then sell it for whatever price they can get.

How do you sell your sweet corn?

There are many options for marketing sweet corn. These include selling:

- to a local merchant;
- to an agent or merchant at the major markets;
- direct to a retailer, for example the major supermarkets or smaller retailers;
- overseas, either direct to buyers or through an exporter.

Know your market

To know your market talk to people who are in constant contact with it, that is your agent/wholesaler/exporter and your retailer. To provide what they want, you will need a quality management system in place.

Determining maturity

Sweet corn must be harvested at the correct stage of maturity to ensure you have a chance of marketing a high quality product. To obtain a product that is sweet, with tender kernels, sweet corn should be harvested at the milk stage. The milk stage is indicated by the slight drying of the silk and the plumpness of the ear when grasped with the hand. The higher the temperature, the shorter the time kernels remain in good edible condition.

Sweet corn matures approximately three to four weeks after the 50% silk stage. It is important to write down when 50% of the cobs are silking and then project a potential harvest date. Check the maturity of your crop a few days before this projected date.

When ready to harvest the kernels at the tip of the cob are approximately 75% full. One way of testing is to squeeze the kernel and the milky fluid will come out or sometimes the embryo will pop out if the cob is mature. Kernel moisture content should be 76% at optimum maturity.

If the flag or husk leaves no longer look fresh and bright green, and/or the ends of the kernels are dimpled, the sweet corn is over mature.

It is difficult to determine the proper stage for harvesting when the husks must be left intact. Pull the husk back on a few ears to test the accuracy of the pickers judgement.

Maturity can quickly be determined by using the microwave drying technique shown below.

Processing

Processing crops are grown under supervision of the processor's field representatives and they will determine when to harvest.

Determining maturity

Within two hours of harvest the moisture level in cobs will begin to decline, usually at rate of 0.25 to 1.00% per day, depending on weather conditions, variety and management.

As well as using the methods above for fresh market sweet corn, processors use a microwave drying technique to monitor and measure cob moisture accurately. This process, shown below, involves taking a sample of sweet corn, weighing it, drying it in the microwave and re-weighing it to determine the moisture percentage. The processor will determine when the crop should be harvested.

The microwave method

1. Randomly select and dehusk 15 cobs and use a sharp knife to remove a slice of kernel material down the entire length of one side of each cob.
2. Put the kernel material in a blender until the kernels become a smooth homogeneous fluid or paste, depending on the maturity of the corn.
3. Weigh two glass petri dishes containing a circle of "Whatman No. 4" ashless filter paper. Record the weight of each to two decimal places. Label one dish '1' and the other '2'.
4. Weigh 5 g of corn slurry onto the filter paper in each dish, smearing it thinly over the filter paper. Record the total weight of the dish (with filter paper) plus sample to 0.01 g for both dishes.
5. Place both dishes in the microwave and turn on for two minutes.
6. After the microwave stops, turn the filter paper upside down, and operate the microwave for another two minutes.
7. After the microwave stops, remove the petri dishes from the microwave with tongs and weigh to two decimal places. Record weights.

8. Return dishes to the microwave and repeat steps 6 and 7 until two consecutive weighings are only 0.01 g apart for each dish.
9. Calculate the moisture content of each sample using the formula below. Average the two results, recording the final figure.

$$\% \text{ Moisture} = \frac{(\text{Wt of dish, paper \& wet sample}) - (\text{Wt of dish, paper \& dried sample})}{(\text{Wt of dish, paper and wet sample}) - (\text{Wt of dish and paper})}$$

Table 39 shows typical moisture levels of sweet corn types at harvest.

Table 39. Typical moisture levels of sweet corn types at harvest*

Type	Moisture level
Supersweets (sh_2 lines including bi-colours) for processing and fresh market	Range 75 – 85% Majority 76 – 81% (Processing 76 – 79%)
Standards (su lines, eg, Jubilee) for processing and fresh market	71 – 73%

*Note: It is very important to consult with buyers, processors and seed companies for specific requirements. Moisture may vary with cultivars.

Growing sweet corn organically

A list of information sources and contacts is given in Chapter 5 pages 253, 240

Organic production is an alternative production system that potential sweet corn growers may consider. The following notes provide a basic outline of key issues for potential producers. Organic production can be very difficult because of the number of pests and diseases that affect sweet corn and its susceptibility to these problems.

The booklet *Organic Agriculture — Getting Started* by David G. Madge, and the *National Standard for Organic and Bio-Dynamic Produce* are excellent information sources for prospective organic producers and well worth reading.

Do some extensive market research to determine the size of the organic market and the prices you can realistically receive for your produce, particularly if it is not of the highest quality. There is an increasing demand for organically grown produce, however the quality and yields achieved may not always be offset by the higher prices that may be received.

Producing crops organically is usually understood to mean production without using synthetic pesticides and fertiliser. The philosophy of organic agriculture, however, is much more than that. Organic production systems are designed to produce high quality food while enhancing soil health, recycling organic wastes, increasing crop diversity and not relying heavily on external inputs. Organic production, therefore, seeks to protect the environment by working with rather than dominating the natural system, the aim is to be sustainable.

more info

Where to get these books Chapter 5 page 250

Organic production is not a low input production system, because the reduced use of external inputs need to be offset by a higher level of management skills. Increased costs will be incurred for labour, alternative methods and materials to control pests, diseases and weeds, and to provide adequate nutrients.

To maximise market advantage, organic producers should seek organic accreditation with one of Australia's organic organisations.

Some points to consider in organic production

Production timing is critical to but does not ensure success. Avoid hot weather production, particularly when frequent rainfalls can be expected as this can make the crop more prone to pests and diseases.

Rotating sweet corn crops with unrelated crops is important to managing disease and weed problems. Most organic farmers have found that weeds are one of the more difficult problems to manage. Income derived from organic production needs to be spread over several different crops. This will reduce the adverse economic effects of a crop lost to pests, weeds or diseases that can be beyond the control of the organic farmer.

Monitor crops regularly for diseases and insect pests to help prevent problems. This is particularly important for managing heliothis caterpillars, a major problem in sweet corn production. A number of beneficial insects, mainly wasps, are associated with sweet corn pests. Shelterbelts of flowering plants will encourage wasp activity by providing a food source of nectar and pollen. This shelterbelt might be natural bush plants or plants along a watercourse, fence line or headland.

more info
Pest & disease management
This chapter, page 167

Organic growers need to be aware of the natural predators of aphids and other insects.

Colour pictures of these natural enemies can be found in the companion book PICTURE GUIDE: Sweet corn problem solver & beneficial identifier.

There are few effective organic control measures for seedling and leaf diseases of sweet corn. Crop rotation, selecting varieties with the appropriate disease resistance, and good farm and crop hygiene practices can help to reduce risks of pest and disease outbreaks.

Organic fertilisers (minerals, manures and compost) are slow release fertilisers, with nutrients being released over some months. The speed of nutrient availability is largely influenced by temperature and moisture. It is more difficult to fine-tune nutrient supplies to the crop with organic fertilisers than conventional ones.

Compost made from animal manures and other organic waste will be required in quantities up to 20 t/ha to provide sufficient nutrients for this intensive crop. The quantity needed will vary with the amount of nutrients in the compost.

Determining maturity

Use the process described under fresh market sweet corn.

Baby corn

Baby corn is hand harvested at the stage when the tips of the silks are just visible and the cobs are around 50 to 100 mm long and about 15 mm in diameter. Different markets may have different preferences for cob size so check the requirements of your market.

Baby corn production is very labour intensive. It is important to select the best variety to grow. Factors to consider include high cob numbers, disease resistance, high yields, good row arrangement of kernels and a strong yellow cob colour. Usually popcorn varieties, for example Snobaby and Snopop, are used because they produce multiple cobs per plant.

Based on 110 000 plants/ha for baby corn production and averaging three cobs per plant, the yield would be 270 000 cobs per hectare at around 2.2 t/ha of husked baby corn.

Varieties

The quality of sweet corn that you produce depends mainly on the variety you plant. Seed companies regularly release new varieties. A variety that performed well in one district or on another farm in your area will not necessarily perform well on your farm. We suggest that you try small areas of new varieties on your farm before making large plantings.

Select varieties

Variety selection is an important decision as there is no one variety that performs best across all planting seasons and production techniques.

more info
Seed companies
Chapter 5 page 241

Ask your seed suppliers for samples of new varieties. Plant varieties for trial alongside your usual varieties so that you can assess a new variety's performance on your farm against your current varieties.

Variety descriptions

The variety descriptions below have been supplied by the seed companies listed. Days to maturity will depend on the location and season. Table 40 shows the codes used to identify the seed companies.

Table 40. Seed company identification

Code	Company	Code	Company
LV	Lefroy Valley (Snowy River)	Sun	Sunland (Harris Moran)
PS	Pacific Seeds	S	Syngenta
SVS	Seminis Vegetable Seeds		

Table 41 shows the codes used to identify disease resistance or tolerance.

Table 41. Disease resistance or tolerance identification

Code	Disease	Code	Disease
A	anthracnose	MDMV	Maize dwarf mosaic virus
CS	common smut	R	rust
HS	head smut	SCLB	southern corn leaf blight
JGMV	Johnson grass mosaic virus	TLB	turcicum leaf blight also known as northern corn leaf blight (NCLB), and northern leaf blight (NLB)

Table 42 shows the legend used to describe the variety type and usage.

Table 42. Variety type and usage identification

Code	Means
SS	supersweet (sh_2)
N	normal (standard) (su)
FM	fresh market
P	processing

Descriptions

Normal or standard (su) varieties

Bliss (LV). (N, P). Formerly UY2188. Early season, maturity 87 days. Plant 220 cm high with cob at 90 cm. Cobs 20 cm x 5 cm with 18 rows of yellow kernels. Tolerance or resistance: R.

Empire (LV). (N, P). Maturity 97 days. Plants are 250 cm high with cobs at 110 cm. Cylindrical cobs 21 cm x 5.4 cm with 22 rows of strong yellow, deep kernels with a tender pericarp. Tolerance or resistance: R, TLB.

Enterprise (LV). (N, P). Formerly UY2138NG. Maturity 97 days. Plants 215 cm high with cobs at 110 cm. Cobs 21 cm x 5.2 cm with 18 rows. Cob slightly tapered, kernel colour slightly pale. Tolerance or resistance: R, TLB, JGMV.

Global (LV). (N, P). Older hybrid. Maturity 96 days. Plants 210 cm high with cobs at 105 cm. Cobs 20 cm x 5.2 cm with 18 rows. Good vigour, sturdy plant style. Slightly pale kernel colour, tender pericarp. Performs well in hotter climates. Tolerance or resistance: R.

Golden Millennium (S). (N, P). Maturity 85 days. Plants 2.85 m high with cobs at 95 cm, stands well in strong winds. Cobs 215 mm x 47 mm, 18 to 20 rows of deep, bright yellow, extra tender kernels. Yields well in cold or adverse conditions. Suited to canned or frozen, cut or whole cob processing. Tolerance or resistance: R, TLB, MDMV, CS, HS.

Heritage (S). (N, P). Maturity 90 to 96 days. Plants 243 cm high, with cobs at 91 cm. Cobs 21 cm x 4.7 cm with 16 to 18 rows of yellow kernels. Tolerance or resistance: R.

Jubilee (S). (N, P). Maturity 90 to 96 days. Plants 243 cm high, with cobs at 91 cm. Cobs 21 cm x 4.7 cm with 16 to 18 rows of yellow kernels. Jubilee was the bench mark for processing sweet corn world wide for many years.

Legacy (Sun). (N, P). Maturity 85 days. Plant 230 cm high with cob at 91 cm. Cobs 21 cm x 4.8 cm with 18 to 20 rows of petite, deep, yellow kernels. High yield and recovery. Tolerance or resistance: R, TLB, CS.

Prelude (LV). (N, P). Early mid season, maturity 90 days. Plant height 200 cm with cobs at 80 cm. Cobs 19 cm x 5.2 cm with 20 rows. High quality and yield, strong yellow kernels, high sugar levels, high kernel recovery. Tolerance or resistance: R.

Rosella 425 (LV). (N, P). Old standard processor in SE Qld, well adapted to sub-tropical conditions. Maturity 95 days. Plants height 200 cm with cobs at 85 cm. Cobs 20 cm x 5.1 cm with 20 rows. Tolerance or resistance: R, TLB.

Untouchable (LV). (N, P). Older processing variety. Maturity 95 days. Plant height 210 cm with cobs at 105 cm. Cobs 21 cm x 5.2 cm with 18 rows. Tolerance or resistance: R, TLB, JGMV.

TripleSweet varieties

Honey Select (S). (TripleSweet, FM). This is a new class of sweet corn with 75% sugary enhanced (se) kernels and 25% supersweet (sh_2) kernels. This provides extra sweetness and shelf life. Maturity 79 days. Cobs 21 cm x 5 cm, 18 to 20 rows of tender, sweet, yellow kernels. Medium green husk with good flags.

Supersweet (sh_2) yellow varieties

Basin (SVS). (SS, FM, P). Main-season, maturity 90 days. Plant 220 cm high with cob at 85 cm, stands very well. Cobs 21 cm x 5.4 cm with 16 to 18 rows of yellow kernels and very good husk cover. Tolerance or resistance: R, MDMV.

Columbia (LV). (SS, P) Formerly HY1012NF. Mid season, maturity 98 days. Plant height 210 cm with cobs at 105 cm. Cobs 20 cm x 5 cm with 18 rows. Cylindrical cobs with moderate tip fill. Tolerance or resistance: TLB.

Dominion (S). (SS, P). Maturity 90 to 92 days. Very vigorous seedlings, plants average 2.4 m, cob height 90 cm. Sturdy erect plants not prone to lodging. Uniform cobs 21.5 cm x 4.7 cm, 18 rows of golden yellow, tender, high quality kernels with high sugars (up to 40%). Similar to Dynasty. Good factory recovery, best harvested at 76% moisture. Tolerance or resistance: R.

Gladiator (LV). (SS, FM, P). Maturity 101 days. The hardy plants are 250 cm high with cobs at 120 cm. Cobs 21 cm x 5.5 cm with 18 rows of yellow kernels and a long shank. It can tolerate high and low temperatures over winter and summer. Suits freezing and canning. Tolerance or resistance: R, TLB, JGMV.

Goldensweet (LV). (SS, FM, P). Maturity 99 days. Plants 260 cm high with cobs at 125 cm. Cobs 20 cm x 5 cm with 18 rows of deep yellow kernels. Cobs have a dark green husk and good tip fill. It has lower than optimum vigour. Tolerance or resistance: R, TLB.

Goldensweet Improved (LV). (SS, FM, P). **(LV).** (SS, P). Formerly HY1116. Mid season, maturity 102 days. Good vigour, plant 235 cm, cob at 100 cm. High quality cobs 19 cm x 5.1 cm with 16 rows of yellow kernels. Improved husk cover and disease tolerance compared to Goldensweet. Suits freezing, canning and powder. Tolerance or resistance: R, TLB.

Hybrix 5 (PS). (SS, FM, P). Formerly Pacific H5. Maturity 90 to 95 days in south east Queensland. Strong plant 200 cm tall resistant to lodging. Cobs 190 cm x 5 cm, slightly tapered, 14 to 16 rows. Light green tight husk with no flag leaves, protects cobs well and reduces cob rot and heliothis damage. Cream kernels with a smooth, sweet flavour. Suits tropical and sub-tropical areas, not suited to Victoria and Tasmania. Tolerance or resistance: R, JGMV, TLB.

Kahuna (LV). (SS, FM, P). Formerly HY1734. Maturity 103 days, temperate variety. Good vigour, plant 245 cm, cob at 110 cm. High quality cobs 21 cm x 5.2 cm with 18 rows of yellow kernels. Suits freezing and canning. Tolerance or resistance: R, TLB.

Krispy King (S). (SS, FM, P). Mid-season, maturity 86 days. Strong, early seedling vigour, not prone to lodging. Cobs 21.5 cm x 6 cm, 18 rows of glossy, yellow, deep, sweet tender kernels. It can be planted in cooler and heavier soils and is very adaptable for all seasons. Must be harvested at 78% moisture. Tolerance or resistance: TLB.

Lancaster (LV). (SS, P). Formerly HY1164. Full season, maturity 99 days. Good vigour, plant 240 cm, cob at 110 cm. High quality cobs 21 cm x 5.2 cm with 18 rows of yellow kernels. Husk cover marginal in some conditions. Suits freezing and canning. Tolerance or resistance: R, NLB.

Magnum (S). (SS, FM). Maturity 85 days. Robust plants stand up well in adverse weather. Cobs 21 cm x 5 cm, 18 to 20 rows of yellow kernels, similar to Dominion. Medium green husk with good tip cover. Suited to sub-tropical areas, harvests easily and cleanly. Tolerance or resistance: R.

Matador (LV). (SS, FM, P). Maturity 103 days. Strong plant 255 cm high with cob at 125 cm. Cobs 21 cm x 5.2 cm with 18 rows of yellow kernels. Excellent tolerance to rust and turcicum leaf blight. Tolerance or resistance: R, TLB, JGMV.

Max (Sun). (SS, FM, P). Maturity 85 days. Plant 195 cm high with cob at 86 cm, has excellent standability. Cobs 19 cm x 4.6 cm with 16 to 18 rows of yellow kernels. Good eating quality and high processing recovery. Tolerance or resistance: R, TLB, MDMV, CS.

Rising Sun (LV). (SS, FM, P). Early season high quality hybrid. Maturity 91 days. Plant 180 cm high with cob at 75 cm. Cobs 19.5 cm x 5 cm with 16 rows. Tolerance or resistance: R, TLB.

Sentinel (SUN). (SS, FM, P). Maturity 83 days. A strong plant with cobs at 76 cm. Cobs 20 cm long, slightly tapered with yellow kernels. Execellent husk protection. Excellent eating quality, tolerance or resistance: R, NCLB, MDMV.

Sovereign (S). (SS, FM, P). Mid-season, maturity 86 days. Strong, early seedling vigour, not prone to lodging. Cobs 21.5 cm x 6 cm, 18 rows of glossy, yellow, deep, sweet tender kernels. It can be planted in cooler and heavier soils and is very adaptable for all seasons. Must be harvested at 78% moisture. Tolerance or resistance: R, TLB.

Supersweet (sh_2) bi-colour varieties

Crunch (LV). (SS, FM). Bi-colour, maturity 99 days. Grower friendly plants are 220 cm high with cobs at 100 cm. Cobs 20 cm x 5.4 cm with 20 rows of yellow and white kernels with excellent eating quality. Plant will cope with a wide range of conditions. Cobs have great colour definition, excellent tip fill and long shelf life. Tolerance or resistance: R, TLB.

Entrée (LV). (SS, FM). Very early bi-colour. Maturity 88 days. Plant height 180 cm with cobs at 40 cm. Cobs 21 cm x 5.4 cm with 16 rows. Large cylindrical cobs and vigorous plants suited to cooler conditions. Tolerance or resistance: R, TLB.

Flair (LV). (SS, FM). Bi-colour, maturity 97 days. Sturdy plants are 220 cm high with cobs at 90 cm. Cobs 19 cm x 5.6 cm with 20 rows of yellow and white kernels with good eating quality. Tolerance or resistance: R, TLB.

Goldenpearl (LV). (SS, FM). Bi-colour, maturity 96 days. Plants 240 cm high with cobs at 110 cm. Cobs 21 cm x 5.4 cm with 18 rows of tender, bright yellow and pristine white kernels. Cobs have excellent tip fill and good husk cover. It is difficult to grow and needs optimum conditions. Susceptible to seedling blights under poor conditions. Tolerance or resistance: R, TLB.

Madonna (SVS). (SS, FM). Early to mid-season bi-colour variety, maturity 80 to 90 days. Clean, uniform plants with good resistance to lodging, 165 cm high with cobs at 55 cm. Cobs to 22 cm x 5.5 cm, 18 to 20 very straight rows of plump, soft, golden yellow and snow white sweet kernels very high in flavour. Excellent husk cover and tip fill. Adaptable and hardy in most growing conditions. Tolerance or resistance: R, TLB.

Samurai (LV). (SS, FM). Bi-colour, maturity 99 days. Plant height 205 cm with cobs at 80 cm. Cobs 21 cm x 5.2 cm with 20 rows. Large cob with deep yellow and bright white kernels. Tolerance or resistance: R, TLB.

Supersweet (sh_2) white varieties

Blizzard (LV). (SS, FM). Formerly HW1287NF. Maturity 93 days. Plant height 195 cm with cobs at 70 cm. Cobs 19 cm x 5.5 cm with 18 rows. Medium sized cob with bright white kernels and good quality. Tolerance or resistance: R.

Everest (LV). (SS, FM). Mid season variety, maturity 96 days. Plant height 200 cm with cobs at 70 cm. Cobs 20 cm x 5.5 cm with 18 rows. Kernel colour creamy white with good quality. Tolerance or resistance: R.

Nutrition

The geological origin, depth, pH and recent cropping history influence the inherent fertility of the soil and your fertiliser program. Adequate plant nutrients in the correct proportion are necessary to produce high yields of good quality cobs.

Plan your nutritional program

Getting the soil ready

The first step in providing adequate nutrition for your crop is to have the soil chemically analysed to determine what elements are available and, perhaps more importantly, what elements will be in short supply. This information is then used to plan a nutritional program and to adjust the soil to the crop's requirements before planting. This will give the plants the best chance to produce a high yield of good quality cobs. Take the sample six to eight weeks before your intended planting date. Follow the sampling instructions supplied by the laboratories.

A soil analysis measures the pH, conductivity, organic matter and the concentration of nutrients in the soil. Results will be interpreted by the laboratory, reseller or your consultant. Your experience of the block of land, future cropping plans and the way you wish to manipulate the growth pattern of the crop will influence your nutritional program.

Soil pH. The pH level is a measure of the soil's acidity or alkalinity on a scale from 0 to 14, with 7 being neutral. A pH of 5 is 10 times more acid than a pH of 6. Sweet corn can perform in a fairly wide pH range of 5.5 to 7.5 but prefers a slightly acid soil, around 6.0 to 6.5. In this range, most major and trace elements present in the soil are available to the plants without being at toxic levels. Figure 33 shows how soil pH affects the availability of nutrients; the width of the band shows nutrient availability at different pH levels.

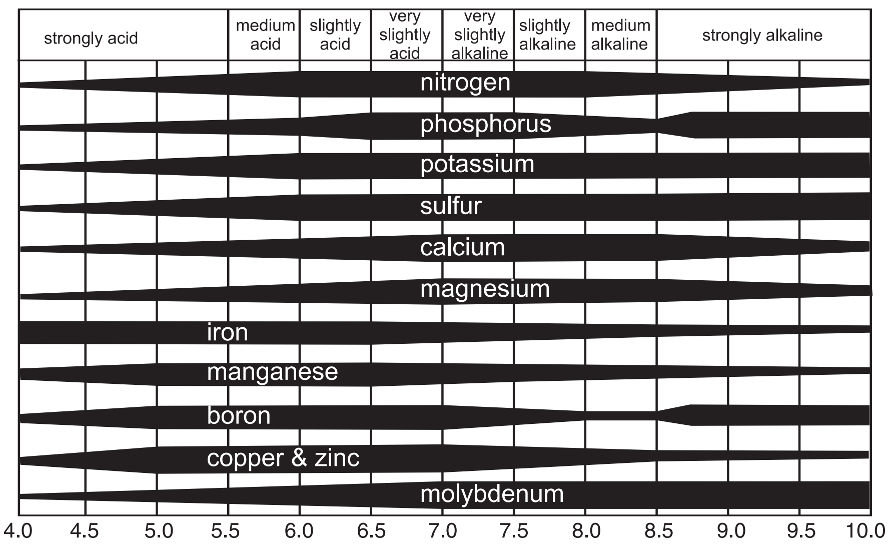

Figure 33. Nutrient availability at different soil pH levels

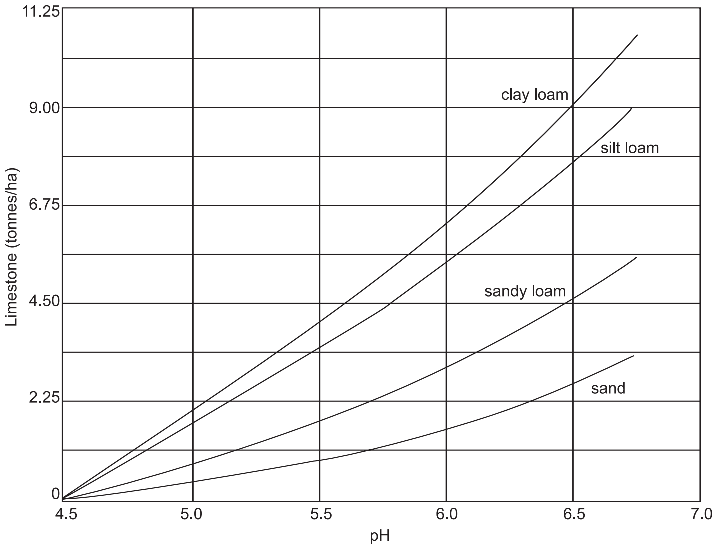

Figure 34. Lime needed to raise soil pH

Source: Matheson et al 1975

Acidic soils require the addition of lime or dolomite to raise the pH and will increase calcium and magnesium levels respectively. A complete soil analysis will show which form is most suitable by showing the available levels of calcium and magnesium. Adjust if pH is below 5.5.

Research has shown that for every tonne of lime applied the pH will change 0.1 to 0.8 units (commonly 0.2 to 0.3 units). A typical commercial application rate is about 2 t/ha of lime. Different soil types require different quantities to change pH. Applications of more than 2.5 t/ha on sandy soils, 4t/ha on loam soils or 5 t/ha on clay soils are not recommended. Figure 34 is a guide to the application rates for lime to raise the pH in the top 18 cm of soil.

Gypsum. Gypsum will increase soil calcium levels but does not change soil pH. As gypsum can also improve the structure of some soils, test your soil to ensure gypsum will help. Naturally occurring gypsum is preferred to phosphogypsum in vegetable crops because of the cadmium in phosphogypsum. The nutrients in gypsum are readily available, however it takes about one year for the physical effects of gypsum on soil structure to become fully apparent. Apply gypsum before the wet season so that it can leach accumulated sodium salts beyond the root zone well before planting, thus improving the soil structure. Soil must have good internal drainage to benefit from gypsum. Table 43 shows the appropriate management of calcium, magnesium and pH.

An application of 5 to 10 t/ha of gypsum can benefit clay loams that have high sodium levels. Table 43 is a guide to which product is most suitable for your situation.

Table 43. Management of calcium, magnesium and pH in the soil

Recommended action	**Soil nutrient status**							
	pH high				**pH low**			
	Calcium high		**Calcium low**		**Calcium high**		**Calcium low**	
	Mg high	**Mg low**	**Mg high**	**Mg low**	**Mg high**	**Mg low**	**Mg high**	**Mg low**
Gypsum 1 – 2 t/ha			✓	✓				
Dolomite 2.5 – 5 t/ha						✓		✓
Lime 2.5 – 5 t/ha					✓		✓	
Magnesium sulphate ($MgSO_4$) 100 – 250 kg/ha		✓		✓		✓		

Sweet corn nutrition

Colour pictures of these natural enemies can be found in the companion book PICTURE GUIDE: Sweet corn problem solver & beneficial identifier.

Sweet corn requires careful nutritional management to ensure high yields of top quality cobs. Follow the recommendations of your soil and plant analyses when applying fertiliser.

Table 44 shows the approximate amount of nitrogen, phosphorus and potassium that sweet corn crops can be expected to remove from the soil. Remember that the elements in the stems, leaves and roots will be returned to the soil when the crop is ploughed in.

Table 44. The amount of nutrients removed from the soil by a 28 t/ha sweet corn crop

Nutrient	Amount of element removed in kg/ha		
	N	P	K
Plant (stems, leaves)	200	24	150
Cobs	110	16	60
Total kg per hectare	**310**	**40**	**210**
Total kg per tonne	**11.1**	**1.4**	**7.5**

Source: C Beckingham, Agfact H8.1.39, *Growing sweet corn*, NSW Agriculture

Major elements

Nitrogen (N)

Nitrogen is required for plant growth and vigour. Plant size and leaf area produced are dependent on an adequate supply of nitrogen. Insufficient nitrogen will result in poorly grown, pale or yellow plants, low yields and small, pale green cobs. Symptoms develop first and are more severe in the older leaves. Low nitrogen levels before tasselling can affect cob size and if low at silking and grain fill will affect kernel development and fill. Large amounts of decomposing organic matter can induce nitrogen deficiency, and then result in high nitrogen levels when decomposition is complete.

Nitrogen is easily leached from the soil by excess rain or irrigation. Nitrogen deficiency is more likely to occur in sandy soils, soils low in organic matter and waterlogged soils.

Phosphorus (P)

Phosphorus is required during the early crop stages for plant development and root growth. Severely phosphorus deficient plants will be stunted with short, thick stems, and short, erect, dark green leaves, though some varieties will have purple or reddish leaves and stems. Symptoms develop first, and are more severe, in the older leaves. Fewer, smaller kernels may develop on cobs.

Deficiency may occur in red or brown soils high in iron (Fe) and aluminium (Al), soils low in organic matter, where topsoil has been eroded and in calcareous soils. Phosphorus is not readily leached from the soil.

Potassium (K)

Mildly potassium deficient plants will be stunted with short, thin stems and pale green leaves. Severely deficient plants will be very stunted with spindly stems and dead lower leaves that hang down around the stem. Symptoms develop first and are more severe in the older leaves. Cobs are often very pointed with poor tip fill and small kernels.

Deficiencies can occur in low organic matter soils, sandy soils, acidic soils below pH 5.4, and alkaline soils above pH 7.5. Potassium is leached from the soil by excess rain or irrigation, but not as easily as nitrogen.

Trace elements

Apply trace elements if deficiencies have developed in previous crops or where soil analysis results suggest possible deficiencies. Some are best applied to the soil before the final cultivation. Soil applications will often last a few years, whereas foliar applications only benefit the plants to which they are applied.

Do not exceed the suggested rates. Adding urea at 500 g/100 L of water will increase the leaf's absorption of trace elements. Spray to wet the leaves to the point of runoff. Solution concentrations greater than 1% are likely to cause leaf burn. Do not apply foliar nutrients with pesticide sprays.

Boron (B)

Boron deficient plants will be stunted with short, stout, oval stems and pale green leaves that are shorter and more erect than normal. Symptoms occur first and are more severe in younger leaves. Fewer and smaller cobs will be produced. Fewer kernels will develop (blanking) because the pollen tube does not grow properly so pollination cannot occur.

WARNING
Solubor is not compatible with zinc sulfate heptahydrate and they should not be mixed.

Boron deficiency is more likely in well-drained, sandy, neutral to alkaline soils, particularly in cool, humid weather. If soils were heavily limed or are low in nitrogen or organic matter a deficiency is more likely. If boron is deficient, follow the suggestions in Table 45.

Zinc (Zn)

Zinc is a very important trace element in sweet corn. Crops may appear patchy, deficient plants will be very stunted with short, stout stems. Leaves of young plants develop bleached areas on each side of the mid-vein on the lower half of the leaf. In older plants, interveinal yellowing or striping occurs. Symptoms occur first and are more severe in younger leaves. Tassels may be distorted and have little pollen in severely deficient plants. Cobs will be small with many missing kernels (blanks).

The availability of zinc decreases at pH levels above 7.0 and below 5.0. High phosphorus levels and wet or cold conditions can induce zinc deficiency. Leached sandy soils and levelled areas where sub-soil is exposed are also likely to show deficiency symptoms.

Soil applications are the most effective way to control zinc deficiency. Applications may be broadcast over the entire area or banded in the rows. The higher rates may remain effective for several years. Zinc may also be applied as a foliar spray, but this should be done within four weeks of emergence.

Soil applications are best made using zinc sulfate monohydrate (35.5% Zn). Zinc sulfate heptahydrate (22.7% Zn) can be dissolved in water and sprayed on the soil using a boom spray or injected through the drip irrigation system.

If a zinc deficiency becomes apparent, apply zinc sulfate heptahydrate or zinc chelate. Use soft water and keep the material well agitated. Table 45 shows the application rates for boron and zinc.

Table 45. Soil and foliar application rates for boron and zinc

Element	Product	Application rate	Comments
Boron	Solubor (20.5% B) Solubor DF (17.4% B)	1.25 – 2.5 kg/ha	Spray on the soil before planting and cultivate it in. Solubor is not compatible with zinc sulfate heptahydrate, do not tank mix.
	Solubor (20.5% B)	250 g/100 L	Foliar spray, 2 to 3 applications 2 weeks apart starting 2 weeks after emergence. Do not exceed a total of 2.5 kg/ha. Solubor is not compatible with zinc sulfate heptahydrate, do not tank mix.
Zinc	zinc sulfate monohydrate (35% Zn)	20 – 30 kg/ha	Broadcast onto the soil before planting and cultivate it in.
	zinc sulfate heptahydrate (22% Zn)	40 kg/ha	Spray on soil or apply through the drip irrigation. Do not mix with boron.
	zinc sulfate heptahydrate (22% Zn)	200 – 250 g/100 L	Foliar spray 3 to 4 applications 1 week apart starting 1 to 2 weeks after emergence. Do not apply on very hot days or in the middle of the day. Do not tank mix with boron.
	Zincsol (16.7% Zn)	2 L/ha	Apply as a foliar spray or with irrigation. Do not mix with boron.

Monitor plant nutrients

Monitoring the plants' nutrient levels allows you to check for nutrient deficiencies in your crop, compare the results with soil tests and plan a better nutritional program for your next crop.

Applying fertiliser every few weeks without knowing whether the plants need it wastes money and is environmentally irresponsible. Take the guesswork out of fertiliser applications by monitoring plant nutrient levels. There are two ways to monitor plant nutrients, leaf testing and sap testing.

Leaf testing

Leaf testing is a benchmarking tool that has little direct relevance to the current crop. Its value is in judging the effectiveness of the fertilising schedule used in this crop and how it may be improved for the next crop. Use the results of soil and leaf testing to refine the fertiliser schedule for the next crop.

Do a leaf analysis at the tasselling to initial silk stage. Buy a tissue sampling kit from your farm supply outlet and follow its instructions. The laboratory analysing your sample will interpret your results and advise what nutrients are needed. The optimum levels for sweet corn for the ear leaf taken at the silk stage are shown in Table 46.

Table 46. Optimum leaf nutrient levels for sweet corn based on dry weight

Nutrient	Normal level
Nitrogen (N)	2.6 – 3.5%
Phosphorus (P)	0.2 – 0.3%
Potassium (K)	1.8 – 2.5%
Sulfur (S)	0.1 – 0.3%
Calcium (Ca)	0.15 – 0.3%
Magnesium (Mg)	0.2 – 0.3%
Chloride (Cl)	0.34 – 0.53%
Copper (Cu)	6 – 20 mg/kg
Zinc (Zn)	20 – 40 mg/kg
Manganese (Mn)	20 – 150 mg/kg
Iron (Fe)	60 – 160 mg/kg
Boron (B)	50 – 70 mg/kg
Molybdenum (Mo)	0.6 – 1.0 mg/kg

Source: Reuter & Robinson, 1997

Sap testing

Sap testing is a means of rapidly assessing a plant's nutrient status during crop growth. This test has a 24 hour turn-around time. It can be used to highlight deficiencies of essential elements or to monitor the nitrate and potassium levels during the crop cycle. Sap testing allows growers to manage the crop more precisely and to correct any nutrient problems before yield or cob quality are affected.

The test involves collecting the youngest fully expanded leaves, extracting sap with a garlic press, and analysing its nutrient content. Sap testing may start when plants have five to six leaves and continue every two weeks to tasselling.

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Plant testing services
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You can do the tests yourself, but we recommend you use a commercial sap testing service for the tests and advice on the results.

Sap testing for nitrogen, phosphorus, potassium, calcium, magnesium, boron and zinc should ideally be done every two weeks. Nitrogen, magnesium, boron and zinc are good indicators of the plants' nutritional health.

Fertilising

Sweet corn requires careful nutritional management to ensure high yields. Follow the recommendations from your soil or plant analysis when applying fertiliser.

Nitrogen is a vital element as is potassium. Low nitrogen levels before tasselling (30 to 50 days after emergence) can affect cob size and if low at silking and grain fill will affect kernel development and fill.

Fertilisers are commonly sold as mixtures of the major elements, nitrogen (N), phosphorus (P) and potassium (K), but are also sold as 'straights' containing only one major element. The percentage of each element is expressed as a ratio of N:P:K. For example 100 kg of a fertiliser with an N:P:K ratio of 15:4:11 contains 15 kg nitrogen, 4 kg phosphorus and 11 kg potassium.

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Using these products
Table 43 page 142

Other elements that are required in relatively large amounts and may also be deficient in some soils include calcium, magnesium and sulphur. Sulphur is usually found in sufficient quantities in most commercial N:P:K fertilisers, superphosphate, gypsum and sulphate of potash. Lime, dolomite and gypsum are sources of calcium. Dolomite and magnesium sulphate supply magnesium. Fertiliser should be applied before or at planting (basal) and as side-dressings, after planting, as the crop grows.

Basal fertiliser

Determine basal fertiliser requirements from a complete soil analysis. The soil type is very important, sandy soils require higher rates of fertiliser than loams, application rates will also depend on previous cropping history.

Basal fertiliser may be spread over the entire soil surface; or in a band over the row and incorporated into the soil during final soil preparation; or drilled in narrow bands 5 cm to the side and 8 cm deep at planting (Figure 11, Chapter 3 page 42). In the Riverina, anhydrous ammonia is commonly used. It is drilled into the soil 15 to 20 cm deep to avoid both gas loss and potential seed damage.

Post-plant (side-dress) fertiliser

Additional fertiliser will be required as the crop develops. Up to 60% of the nitrogen required by the plant is taken up in the two weeks before and two weeks after tasselling. It is essential that the plant has adequate nitrogen once silking commences or tip fill will be affected.

Post-plant fertiliser can be drilled in beside the row (Figure 35), at the last cultivation; broadcast over the crop using a spinner applicator or aircraft; or applied through the irrigation system (fertigation).

Figure 35. *Side-dressing fertiliser being drilled in beside the row*

When and how you apply side-dressing fertiliser will depend largely on how you irrigate your crop. How much side-dressing fertiliser you apply should be based on soil or leaf analysis. Tables are provided below for Queensland, NSW and Victoria. They give a general guide to the additional amount of N to apply to the crop as side-dressings. If potassium levels are low, additional potassium may also be required at this time. If irrigation is being monitored with scheduling equipment and fertiliser leaching is controlled the post plant application may be reduced.

Fertilising through irrigation water (fertigation)

Fertiliser can be applied through overhead sprinklers, furrow irrigation (called 'water run') or drip irrigation systems. Fertigation uses less labour than manual application of solid fertilisers. With these systems fertilisers can be applied more regularly and closer to the roots. Before fertigating get a water-testing laboratory to analyse your irrigation water.

With drip and overhead fertigation, fertiliser is dissolved in water in a drum or tank and sucked or injected through the watering system. Fertilisers used must be highly soluble to avoid damaging the pump and blocking pipes. Suitable soluble fertilisers are listed in Table 47. There is also a range of soluble commercial fertiliser blends.

For fertigation with furrow irrigation, the dissolved fertiliser in the tank is metered into the top supply channel then syphoned down every furrow. Urea is the most common product used. With this system there is less damage to equipment and fewer blockages as the soluble fertiliser does not have to go through pumps or filters.

Table 47. Fertilisers that can be dissolved in water for fertigation

Fertiliser	Elements applied	% of elements
Urea	Nitrogen	46% N
Calcium nitrate	Calcium, nitrogen	18.8% Ca, 15.5% N
Ammonium nitrate	Nitrogen	34% N
Magnesium sulphate	Magnesium, sulphur	9.6% Mg, 12.4% S
Potassium nitrate	Potassium, nitrogen	38.3% K, 13 % N
Potassium chloride	Potassium, chlorine	50% K, 50% Cl
Potassium sulphate	Potassium, sulphur	41% K, 18% S
MAP (mono ammonium phosphate, technical grade)	Nitrogen, phosphorus	12% N, 26.6% P
MKP (mono potassium phosphate)	Potassium, phosphorus	28.6% K, 22.8% P
Various soluble commercial mixtures	Nitrogen, phosphorus, potassium, some with trace elements	Varies eg 21% N, 9% P 16% K

Fertiliser application rates

Fertiliser application rates should always be based on soil or plant analyses, however if these are not available the programs shown in Tables 48 to 54 may be used as a guide.

Queensland fertiliser application rates

Basal fertiliser

For fresh market crops apply a basal fertiliser that will supply about the following amounts of major nutrients: 90 kg of nitrogen (N), 25 kg of phosphorus (P) and 70 kg potassium (K) per hectare. Apply the fertiliser in a band at planting, or incorporate into the plant rows with the final cultivation before planting. Table 48 shows fertiliser rates for an N:P:K mixture commonly applied in Queensland.

Table 48. Fertiliser rates and element supplied for a common N:P:K mixture in Queensland

N:P:K mixture	Quantity to apply	Element applied (kg/ha)		
	kg /ha	N	P	K
15:4:11	600	90	24	66

Side-dressing drip irrigated crops

Fertiliser is easy to apply through a drip irrigation system. Table 49 is a guide to nitrogen application rates through drip irrigation systems in Queensland. Make two applications of N fertilizer, one at the four leaf stage and one at early tasselling. If the soil is known to be very low in nitrogen, an additional application of N can be made between the four leaf stage and tassel emergence.

If additional K is required, it can be supplied as potassium nitrate (KNO_3) or as a soluble N:P:K mix, for example a 21:9:16 mix.

Table 49. A guide to side-dress applications for drip irrigated crops in Queensland

Nutrient	Plant stage	Amount of N (kg/ha)	Amount of K (kg/ha)	Rate (kg/ha)			
				Urea (46% N)	Nitram (34% N)	Soluble N:P:K (21:9:16)	KNO_3 (13:0:38)
Nitrogen	4 leaf stage	30	–	65	88	–	–
	intermediate (optional)	16	–	35	47	–	–
	early tassel emergence	30	–	65	88	–	–
Nitrogen and potassium	4 leaf stage	30	23	–	–	143	–
	intermediate (optional)	16	46	–	–	–	123
	early tassel emergence	30	23	–	–	143	–

Side-dressing overhead or furrow (flood) irrigated crops

For furrow irrigation, drill into the irrigation furrow before watering. Drill in beside the row or broadcast over the crop using a spinner applicator or aircraft if overhead irrigating.

Fertiliser can be applied in one or two applications. If making only one application, apply it at the latest stage you can drive over the crop. For two applications apply the first one at the four leaf stage and the second at the latest stage you can drive over the crop. Table 50 is a guide to side-dressing fertiliser requirements in Queensland.

Table 50. A guide to nitrogen application for overhead or furrow irrigated crops in Queensland

Fertiliser	Rate of fertiliser per application		
	1 application	2 applications	
		first application	second application
Urea	130 kg/ha	65 kg/ha	65 kg/ha
OR			
Ammonium nitrate	176 kg/ha	88 kg/ha	88 kg/ha

New South Wales fertiliser application rates

Basal fertiliser

In the central west growers commonly drill urea into the soil as a basal fertiliser about a week before planting. At planting mono ammonium phosphate (MAP) and sulphate of potash are applied to give a total basal fertiliser for the central west of 120 kg of N, 44 kg of P and 41 kg of K per hectare.

In the Riverina, growers commonly inject anhydrous ammonia 15 to 20 cm into the soil, 3 to 4 weeks before planting and apply MAP at planting. This is a total basal rate for the Riverina of 135 kg of N and 44 kg of P. Potassium may be applied if indicated by soil tests. Table 51 shows the basal fertilisers commonly used in NSW.

Table 51. Fertiliser rates and elements applied in NSW

District	Fertiliser applied	Time of application	Quantity to apply	Element applied (kg/ha)			
			kg /ha	N	P	K	S
Central west	urea	1 week before planting	217	100			
	MAP	at planting	200	20	44		0
	sulphate of potash	at planting	100			41	18
			Total	**120**	**44**	**41**	**18**
Riverina	anhydrous ammonia	3 – 4 weeks before planting	140	115			
	MAP	at planting	200	20	44		
			Total	**135**	**44**	**0**	**0**

Side-dressing fertiliser

In NSW it is common practice to make the first side-dress fertiliser application with a cultivation at the latest stage you can drive over the crop, about the six to eight leaf stage. Growers then fertigate, water running nitrogen by furrow, or applying it through centre pivot irrigators in several small amounts through until early tassel emergence. When travelling irrigators are used, a single application is drilled in at the six to eight leaf stage, then watered in with the travelling irrigator.

Total nitrogen requirements for the Sydney Basin and the Central West are similar with about 220 kg/ha total nitrogen required throughout the growing season. To ensure high yields in the Riverina, growers need about 250 kg/ha total nitrogen. The higher nitrogen requirements needed in the Riverina are due to the irrigation method, soil fertility and inefficiencies in nitrogen uptake.

Central West. If travelling irrigators are used only one application is made at the six to eight leaf stage. If using centre pivots, one initial application is made, then several more as needed, up to the early tassel emergence stage.

Riverina. If using furrow irrigation one large application is made with the final cultivation at the six to eight leaf stage, then water run as needed up to the early tassel emergence stage.

Table 52 is a guide to side-dressing fertiliser requirements in New South Wales.

Victorian fertiliser application rates

Basal fertiliser

Basal fertiliser can be banded separate from the seed, or on less fertile soils, drilled in at a higher rate. Table 53 shows the basal fertilisers commonly used in Victoria.

Side-dressing fertiliser

Side-dressing applications should be based on a soil test, previous cropping history or a sap test. Apply around 110 kg/ha of nitrogen as one or more side-dressings. Start side-dressing about 30 days after emergence when the rapid growth stage begins and have all side-dressings applied by early tasselling. If the level of potassium in the soil is low a side-dressing of up to 500 kg of a 20:0:16, N:P:K mixture may be a better alternative. Table 54 is a guide to side-dressing fertiliser requirements in Victoria.

Foliar fertilisers

Foliar fertilisers contain soluble nutrients that are sprayed on the crop and absorbed through the leaves. They may be urea, potassium nitrate or magnesium, specific trace elements or a ‘shotgun’ mixture of many major and trace elements dissolved in water.

As the plant’s primary means of absorbing nutrients is through the root system, foliar fertilisers should not be used to replace soil applications, particularly for the major elements. However where specific trace element deficiencies have been identified, or disease, nematodes or waterlogging have made the roots ineffective, foliar fertilisers may help the plants survive until new roots develop and can again support them.

Table 52. A guide to nitrogen application for overhead or furrow irrigated crops in New South Wales

District	Irrigation method	Time of application	Fertiliser applied	Number of applications	Quantity to apply (kg /ha)	Total applied (kg /ha)
Central west	travelling irrigator	6 – 8 leaf stage	urea	1	174 – 217	174 – 217
	centre pivot	6 – 8 leaf stage	urea	1 plus	65	65
		up to early tasselling	urea	several	110 ÷ number of applications	110
Riverina	furrow	6 – 8 leaf stage	urea	1 plus	150	150
		up to early tasselling	urea	several	110 ÷ number of applications	110

Table 53. Fertiliser rates and element supplied for a common N:P:K mixture in Victoria

N:P:K mixture	Soil fertility	Quantity to apply	Element applied (kg/ha)		
		kg /ha	N	P	K
12:12:17	good – average fertility	500	60	60	85
8:10:10	good – average fertility	600	48	60	60
12:12:17	low fertility	700	84	84	119
8:10:10	low fertility	900	72	90	90

Table 54. A guide to nitrogen application for overhead or furrow irrigated crops in Victoria

Time of application	Fertiliser applied	Number of applications	Total applied (kg /ha)
30 days after emergence	urea	1 or more	200 kg/ha
	OR		
30 days after emergence	calcium ammonium nitrate ($CaNO_3$)	1 or more	300 kg/ha
	OR		
	potassium nitrate (KNO_3) (if potassium is low)	1 or more	300 kg/ha
	OR		
30 days after emergence	20:0:16		up to 500 kg/ha

Irrigation and water management

Irrigation management is one of the keys to producing a high yielding, good quality sweet corn crop. An efficient irrigation system applying good quality water, and accurate scheduling devices, are essential to ensure that the plants receive the correct quantity of water when they need it.

Water requirements

Water quality

Sweet corn is moderately sensitive to saline irrigation water and is most sensitive when very young. When grown under furrow or drip irrigation, water with an electrical conductivity (EC) up to 2.2 deciSiemens per metre (dS/m) can be used on some soils provided careful management practices are followed. Sweet corn grown under overhead irrigation is more sensitive to saline irrigation water because of leaf contact with the water. Damage may occur when overhead irrigating if the water has a conductivity above 1.5 dS/m. A yield reduction of 25% or more may occur if water with EC levels above 2.5 dS/m is used. Table 55 shows the water conductivity threshold for yield reduction for different soil types.

Table 55. Conductivity above which yield may be reduced

Soil type	Sand	Loam	Clay
Conductivity	2.2 dS/m	1.2 dS/m	0.7 dS/m

Source: NRM Facts, water series W55

Until recently water conductivity was reported in microSiemens per centimetre (µ/cm), however it is now reported as deciSiemens per metre (dS/m).

To convert from µ/cm to dS/m use the following formulae.
microSiemens per centimetre (µ/cm) divided by 1000 = deciSiemens per metre (dS/m)

Example: 2200 (µ/cm) ÷ 1000 = 2.2 (dS/m)

To convert from dS/m to µ/cm use the following formulae.
deciSiemens per metre (dS/m) multiplied by 1000 = microSiemens per centimetre (µ/cm)

Example: 1.2 (dS/m) x 1000 = 1200 (µ/cm)

Water quantity

Sweet corn needs 4 to 8 megalitres (ML) per hectare of water for overhead irrigation depending on the length of the crop. Queensland crops tend to be ready for harvest in less time than crops in southern states. The quantity required may be significantly reduced when using drip irrigation. For furrow irrigation the figure can vary from 6 to 10 ML per hectare.

The amount of water required also varies with the locality and the soil type. Sandy soils have a much lower water-holding capacity than clay-based soils and consequently need more frequent irrigation. The soil texture will also determine the amount of water applied at any one time. Water requirements are higher in hot weather than cool weather. As a general rule sweet corn requires 30 to 60 mm of rain and/or irrigation per week. Requirements for advanced sweet corn may increase to 80 or 90 mm per week during hot weather. Furrow irrigators may have to irrigate every five to seven days in hot weather.

Irrigation must No. 1—a good irrigation system

Consult an irrigation equipment supplier or designer in your area and get them to develop an irrigation plan

The first essential requirement of efficient irrigation is a water supply and irrigation system capable of delivering the required amounts of water when needed.

Irrigation methods

Overhead, drip and furrow irrigation are all used in sweet corn production.

Overhead irrigation

Overhead irrigation includes fixed and travelling irrigators (single jets and booms) and sprinklers including hand move, centre pivot, Figure 36, and lateral move systems. Overhead irrigation is suitable for any soil type and undulating country. Table 56 shows the advantages and disadvantages of overhead irrigation. Table 57 lists some of the overhead irrigation systems available and their associated costs in NSW.

Figure 36. *A centre pivot irrigator*

Table 56. Advantages and disadvantages of overhead irrigation

Advantages	Disadvantages
Easier than furrow irrigation to regulate water application	Washes spray off plants
Can be used in most situations	Expensive to set up
Can apply fertilisers with irrigation	Wets interrow and headland areas, promoting weed growth
Can apply some pesticides with irrigation	High pumping costs because it requires high pressure, particularly for travelling irrigators
	Affected by wind, reducing even distribution
	Difficult to apply regular, small amounts
	High water use
	Must use high quality water
	Difficult to achieve uniformity, particularly in tall crops

Table 57. Some overhead irrigation systems and their associated costs in NSW

Irrigation system	Area (ha)	Capital cost ($/ha)	Annual costs ($/ha)					
			Depreciation	Interest	Pumping	Repairs	Labour	Total
Hand move	25	$1 500	$78	$128	$240	$50	$1230	$1 726
Power side roll	25	$2 600	$140	$220	$110	$85	$50	$605
Bike shift	25	$1 500	$78	$128	$80	$50	$20	$356
Travelling irrigator, soft hose	25	$2 400	$125	$205	$190	$90	$38	$648
Travelling irrigator, hard hose	25	$2 900	$150	$245	$190	$100	$30	$715
Travelling irrigator, fixed boom	25	$3 200	$175	$270	$600	$115	$40	$1 200
Centre pivot	60	$2 400	$150	$205	$75	$105	$5	$540

Source: Chris Rolfe, NSW Ag. (March, 2001)

Drip (trickle) irrigation

Drip irrigation is widely used in north Queensland and Bundaberg, and has given substantial savings in water use.

Drip irrigation is the most easily controlled method. The equipment is expensive, but has a long life. If drip tubing is to be re-used, treat it with chlorine to reduce the risk of blockages. Soluble fertiliser mixtures and some pesticides can be applied easily through the irrigation system.

Use a drip tube with outlets no more than 20 cm apart. A commonly used drip irrigation tube with 20 cm outlet spacing and operated at 0.55 bar (8 psi) inlet pressure should deliver about 500 L per 100 m of row per hour. The actual quantity applied will vary depending on the amount of slope and the pressure. Table 58 shows the advantages and disadvantages of drip irrigation.

Table 58. Advantages and disadvantages of drip irrigation

Advantages	Disadvantages
Does not wet plants and wash off sprays	Requires a greater intensity of management
Easy to regulate applications	Requires regular maintenance during the growing period
Can apply small amounts often, (daily if necessary)	Can block up if good filters are not used in the critical period
Only wets the root area	High initial cost
Can easily apply nutrients to the root zone	Not suitable for steeply undulating country because of output variability
Not affected by wind	Susceptible to damage by crickets
Can use poorer quality water than overhead systems	Must filter water and/or treat it for iron bacteria
Uses less water than other systems	
Increased yields	
Cheaper pumping costs because it requires low pressure	

Furrow irrigation

Furrow irrigation is not commonly used in Queensland but is in the Riverina region of NSW. It requires an even, gentle slope and a soil type that allows water to spread laterally without penetrating too deeply.

Furrows longer than 200 m are not recommended in Queensland. For the self mulching grey soils in the Riverina the recommend maximum run length is 400 m, with 300 m considered the optimum. Recommended slope for this soil type would be 1:1000 to 1:1200. For the red brown earths, where soils do not sub (allow water to soak laterally to the centre of the bed) as easily, maximum run lengths of 300 m are recommended. The slope can be a bit flatter at about 1:1200 to 1:1400.

Water from the end of the rows must be removed to prevent waterlogging of the lower section of the block. Table 59 shows the advantages and disadvantages of furrow irrigation.

Table 59. Advantages and disadvantages of furrow irrigation

Advantages	Disadvantages
Cheap to set up and operate	High water use
Does not wash spray off plants	Often have wet row ends and waterlogging
Not affected by wind	Difficult to apply fertilisers evenly with irrigation
Can use poorer quality water than for overhead irrigation	Can result in erosion if slope is too steep
	Must have level ground
	Poorer weed control

Irrigation must No. 2—a monitoring system

As soil moisture monitoring can be complex, seek expert advice first, particularly when setting up the system.

The second essential requirement of efficient irrigation is a monitoring or scheduling system to tell you when and how much water your crops need. Research has shown that monitoring can reduce water use considerably without affecting yield or cob quality. Monitoring enables you to ensure you are applying enough water at the critical times.

A range of equipment and techniques is available for monitoring soil moisture and scheduling irrigation. Equipment includes the neutron probe, Enviroscan, Time Domain Reflectometry (TDR), DRW Microlink and Aquaflex. To ensure accurate readings, take care to maintain equipment properly to keep it in good working order.

The most common are the soil-based systems using tensiometers or soil capacitance systems. The other technique sometimes used is a climate-based system that uses estimates of evapotranspiration. The tensiometer or capacitance systems are preferred and recommended. A brief comparison of the main systems is shown in Table 60.

Managing water to produce quality sweet corn

Good water management is essential to produce quality sweet corn. The best way to manage water application accurately is to use an irrigation-scheduling device. Inaccurate irrigation is a major cause of poor nutrition. Monitoring both irrigation and nutrition gives you the best chance to achieve maximum profits.

Remember that pesticide applications, irrigation systems, labour, the availability of water and disease risk all influence your decision to irrigate.

Table 60. Comparison of the main soil moisture monitoring systems

System	Advantages	Disadvantages
Tensiometers	Relatively cheap Easy to install Can be read by growers Continuous monitoring	Labour intensive to collect and record data in extremely wet or dry soil Require regular maintenance Can be inaccurate
Capacitance probe	Continuous monitoring Accurate at all depths and for all soils Enables rapid reading and recording of results A range of options for downloading data, direct and remote	Expensive Need skill to correctly interpret data

A strategy for irrigating sweet corn

Planting to emergence. Ensure adequate moisture near the surface for a good strike and to allow the plant to begin to access the basal fertiliser application.

Emergence to tasselling. After successful establishment let the soil dry out slightly from the surface, without stressing plants, to encourage a bigger root system and root development down to 30 to 50 cm. This allows roots to access a larger volume of soil nutrients and moisture, making them less susceptible to a short term water shortage. Cob initiation occurs from weeks four to six. The most critical time to prevent any moisture stress is from three weeks before silking to two weeks after silking.

Tasselling to harvest. Once cobs have set, maintain soil moisture near the full point (field capacity) by not allowing the crop to take more than 50% of the available moisture. This facilitates pollination.

Table 61 shows the readings on the shallow tensiometer (20 cm), at which you should irrigate, for the different stages of plant growth. Irrigate when the tensiometer reading reaches the appropriate figure below. If the tensiometer stays below 10 kPa the soil is too wet.

Table 61. Tensiometer readings at which to commence irrigation

Soil type	Tensiometer reading	
	Establishment to tasselling	**Tasselling to harvest**
Sandy loams	40	35 – 40
Clay soils	45 – 60	40 – 50

Tensiometers

A tensiometer consists of four basic parts—a hollow tube filled with water and algaecide, a ceramic tip, a water reservoir and a vacuum gauge which reads water tension on a scale of 0 to 100 centibars (kiloPascals kPa) (Figure 37). In more complex systems, the conventional vacuum gauges are replaced with pressure transducers or portable electronic readers that can download the readings onto a computer and graph the results. These graphs are a record of readings for the season and make it easier to estimate when the next irrigation will be required.

In wet soil, the vacuum gauge will read 0 to 5 kPa. As the soil dries over several days, water moves from inside the instrument, through the porous ceramic tip, into the soil. The gauge reading steadily increases, to a maximum of about 90 kPa. When the soil is re-wet after rain or irrigation, water moves from the soil back into the tensiometer and gauge readings fall.

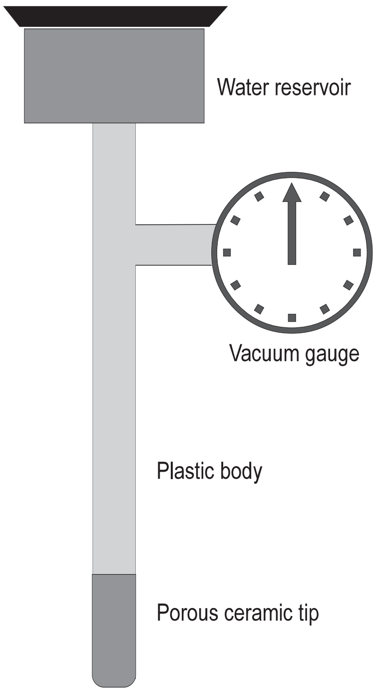

Figure 37. Parts of a standard tensiometer

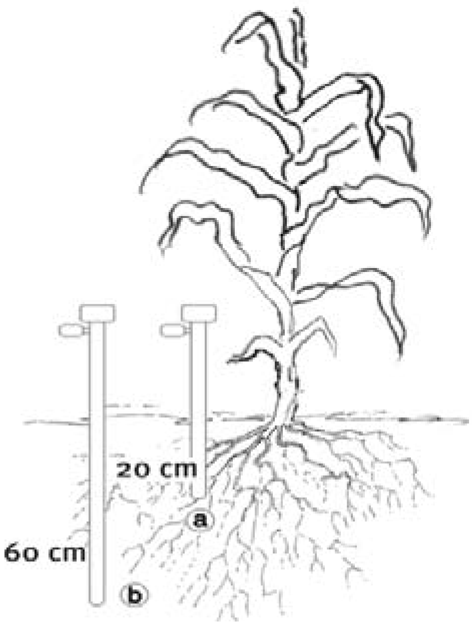

Figure 38. Profile of a typical tensiometer monitoring site in sweet corn

A monitoring site consists of one shallow tensiometer installed in the major root zone and one deep tensiometer below most of the roots (Figure 38). Each planting should have at least two monitoring sites. Shallow tensiometers should be placed within 10 cm of the crop row and midway between plants, though this can vary slightly. Install the shallow tensiometer with the tip 20 cm below ground and the tip of the deep tensiometer 60 cm deep. Install tensiometers after the crop is established, disturbing the plants and surrounding soil as little as possible.

The shallow tensiometer indicates when to water. The deep tensiometer indicates when the right amount of water has been applied. If deep tensiometer readings fall to less than 10 kPa within two days after irrigation, there is more water than the root zone can hold. Constant values after irrigation indicate the root zone is saturated. If readings continue to rise immediately after irrigation, not enough water has reached the root zone.

Installation

Assemble tensiometers and fill with good quality water to which algaecide has been added. Leave them to stand in a bucket of water at least overnight, but preferably for one to two days. The water does not need to be pre-boiled. Tensiometers are more reliable if an appropriate vacuum pump is used to remove any air. If necessary top up the tensiometers with more water, then they are ready to install.

Carry the tensiometers to the installation site with the tips either in water or wrapped in wet rags. Provided the ground is moist and well cultivated, the shallow tensiometer can be pushed 20 cm into the soil. Don't push too hard. The tips are strong but can crack under excessive pressure. Only experience teaches how hard is too hard. At about $40 per tip, this can be an expensive lesson. If you reach a hard soil layer, take the tensiometer out and try somewhere else or use the deep tensiometer procedure.

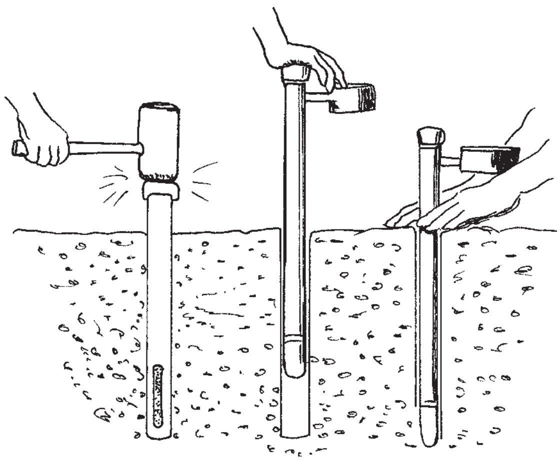

Figure 39. Installing deep tensiometer

To install the deep tensiometer, Figure 39, dig a hole 60 cm deep, keeping the excavated soil nearby in a pile. A 50 mm auger is the best tool. Put the tensiometer in the hole, over to one side. The next step is critical. Good contact between the ceramic tip and the surrounding soil is most important.

Take the most crumbly, moist soil from the dirt pile and pack it around the tip at the base of the hole. A piece of 10 to 15 mm diameter dowel is useful for packing. Don't over-compact the soil into plasticine, but remove any large air gaps. Continue replacing soil until the hole is filled. It doesn't matter which soil you use once you have packed the first 5 cm above the tip. Friable topsoil from a few metres away can be used to create a slight mound around the tensiometer. This minimises water draining down beside the tensiometer, causing false readings.

Covers made from silver/blue insulation foil placed over the tensiometers minimise temperature fluctuations and algal growth. The gauge can be left exposed for easier reading.

The DPI&F has published a useful booklet—*Water it right: a guide to using tensiometers*. more info Where to get this book Chapter 5 page 253

The tensiometers are then ready to operate. Use the vacuum pump to again remove air bubbles. Tensiometers may take a few irrigation cycles to settle down, so don't take too much notice of the readings for the first few days. During this period, air gaps may appear in the tensiometer. Simply refill with algaecide-treated water. Within a week of installation, readings should rise and fall with irrigation and rainfall. Clearly mark tensiometer locations to prevent damage by tractors, harvesters, rotary hoes or other machinery.

Reading

Always read tensiometers at the same time, early in the day, preferably before 8.00 a.m. At that time there is little movement of water in the soil or plants and they are almost in equilibrium. Errors caused by heating of the gauge or water column are also avoided. Read at least twice a week, but preferably every one to two days. Lightly tap the gauge before reading.

It is a good idea to plot the daily readings on a chart. This will show what has happened in the past, for example when crops were irrigated and whether it affected the deep tensiometer. Tensiometers that are read using an electronic gauge, then downloaded onto a computer, automatically graph the readings. By extending the line on the chart it can be used to predict when the next irrigation will be needed. Figure 40 shows diagrammatically how the tensiometer reacts to different amounts of irrigation whilst Figure 41 is a sample chart with shallow and deep tensiometer readings plotted over several irrigations.

Maintaining tensiometers

Ensure that the water level is topped up regularly in the tensiometer. It is best to do this after irrigation when the water level should not be more than 3 to 5 cm below the gauge. It will probably be more than this just before irrigation is due. Use a vacuum pump to remove air bubbles if the water level was very low. After removal from the soil, protect the tensiometer tip from dry air until it has been emptied, cleaned and dried.

A. Shortly after a good irrigation.
B. By extending the line from A through B, you can predict when an irrigation will be needed.
C. Just before irrigation.
D. After an irrigation which did not penetrate adequately.
E. Soil dried sooner because of inadequate irrigation.
F. Reflects an adequate irrigation following E.
G. It is helpful to show the date and hours of irrigation.

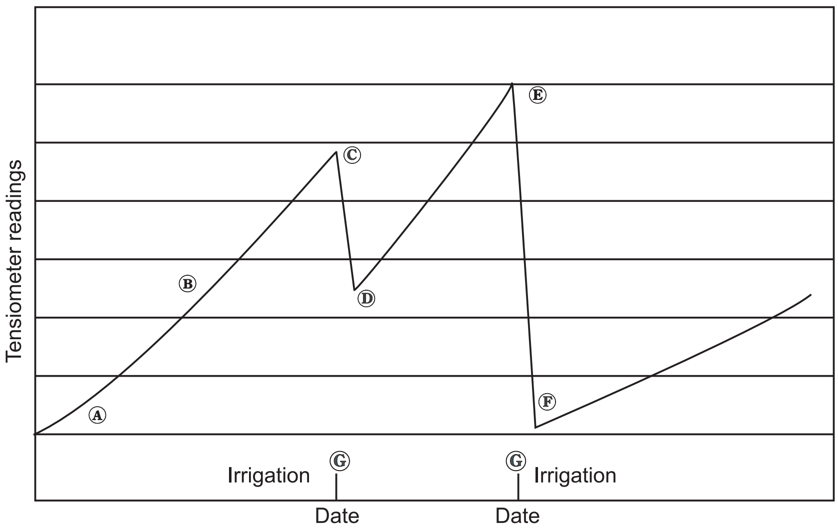

Figure 40. Diagrammatic representation of tensiometer reaction to different amounts of irrigation

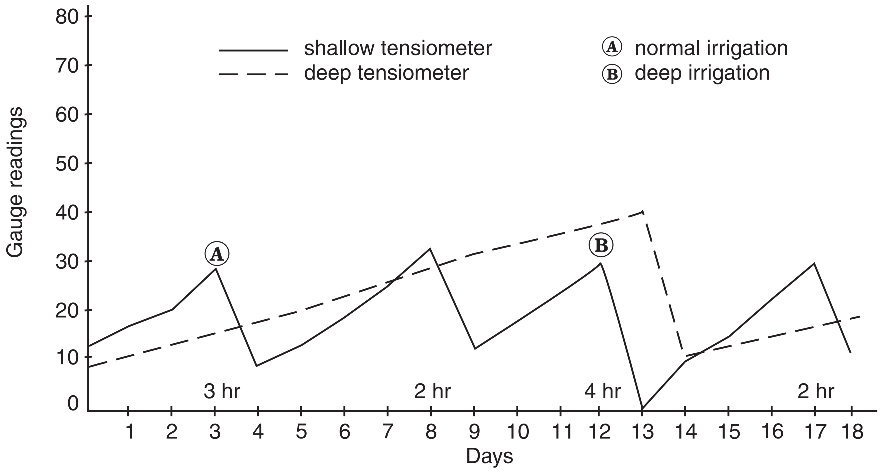

Figure 41. A sample chart showing tensiometer readings plotted daily

Troubleshooting tensiometer problems

No water in the tensiometer; gauge reads 0

Fill the tensiometer with water and apply suction with a vacuum pump. A stream of large bubbles will indicate the problem area, usually a cracked ceramic tip or a missing o-ring seal.

Air entering over several days; gauge registering more than 5

There is either a hairline crack in the tip or a substantial air gap in the soil around the tip. Remove the tensiometer. If there are no obvious tip cracks, re-install the tensiometer. If the problem persists, replace the tip.

No change in readings over several days

The gauge may be faulty or blocked. Check that the gauge is working.

- Apply suction to the tensiometer with a vacuum pump. If the needle does not move there is a problem with the gauge.

Tensiometer readings increase beyond 80 then fall to 0, accompanied by air in the tensiometer

The soil has become too dry for the tensiometer to operate. After irrigation, refill the tensiometer and treat as if it had just been installed. If this happens frequently, consider whether you are under irrigating. If you are happy with your irrigation, try installing the shallow tensiometer slightly deeper. This problem should never happen with the deep tensiometer.

Getting started with tensiometers

A good grower starter pack would include two 30 cm and two 60 cm tensiometers, a suitable vacuum pump and algaecide, and cost about $800. The best tensiometers have replaceable tips, gauges and reservoirs. Some new tensiometers include an in-built pump, but are more expensive.

The more complex systems such as Soilspec, that have portable electronic readers instead of inbuilt pressure gauges could be cheaper if you intend using several sets of tubes. They also have the advantage that you can download the readings onto a computer which graphs the results.

Tensiometers should be installed at two monitoring sites in a crop. Continue usual irrigation practices and get a feel for how tensiometers operate. Once you are comfortable with using them, make slight changes to your irrigation and observe what happens. For example, if the reading of the deep tensiometer always falls after irrigation, reduce the amount of water you apply.

Tensiometers are easiest to use in overhead irrigated crops; flood, furrow and drip irrigation systems are more complex because the positioning of the tensiometer is more critical.

Capacitance probes

Capacitance probes are continuous moisture monitoring devices based on capacitance sensors. They continuously measure the dielectric constant of the soil and consequently its water content. As the soil's water content increases, so does its dielectric constant. Dissolved salts do not significantly affect this reading, which means that fertiliser applications or irrigation water quality do not alter the soil moisture estimates. There are two types of capacitance probes: permanent and portable probes.

In permanent systems, for example Enviroscan, the sensors are mounted on probes, which have slots every 10 cm to accommodate the snap-in sensors. The probes are placed in vertical PVC access tubes installed in the soil after the crop is established. The probes and tubes are left in place until the end of the season.

Sensors are positioned on the probes to provide readings at specific depths. Measurements from the sensors are relayed at regular intervals to a data logger for recording. Data from the logger are downloaded to a computer every few days to show water use and to provide recommendations for watering. Figure 42 is a diagrammatic representation of an Enviroscan probe.

With portable probes, for example the Diviner, the probes have a single sensor head which is carried from site to site and lowered into vertical PVC access tubes installed in the soil after the crop is established. Readings are taken at the required depths. The sensor is connected to a hand-held data logger for on-site display of the soil moisture profile and downloading into a computer. Portable probes are less expensive than permanent probes, but do not allow continuous monitoring.

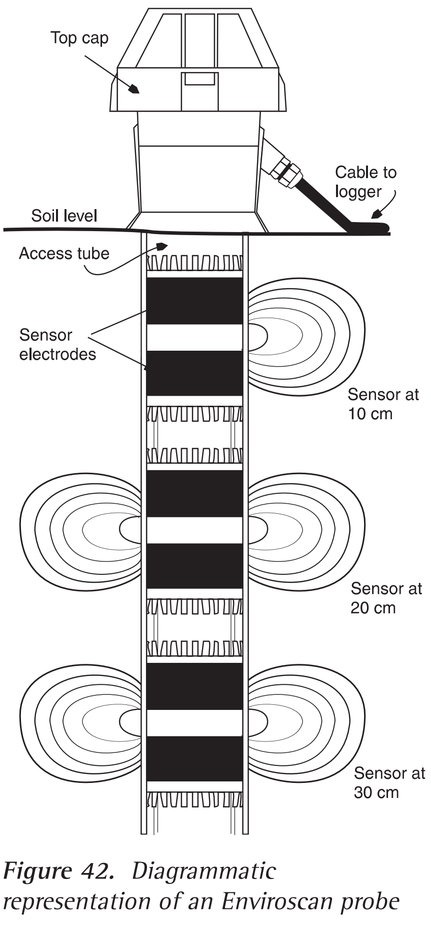

Figure 42. Diagrammatic representation of an Enviroscan probe

With both systems, after downloading, the computer analyses the data and provides an accurate and dynamic understanding of the crop's daily water requirements and the effectiveness of irrigation and rainfall. Results are presented in millimetres of precipitation required to bring the soil water content up to field capacity and irrigation watering time is then easy to calculate. Data are displayed as readily available soil water, water deficit and total soil water over the nominated root zone depth. This information removes the guesswork from irrigation decisions and provides a basis for further manipulation of the crop.

For sweet corn, two probes are recommended for a block of plants but the number of sites depends on the variability in soil and varieties. The probes should have sensors at 10, 20, 30 and 50 cm.

The current cost of a logger, solar panel, 100 m of cable, two 50 cm probes, eight sensors and software is about $5000. Equipment can also be hired from some consultants.

Interpretation of the data requires skill. We recommend that consultants be used to set up the system and provide at least the initial advice.

Maintenance of a drip irrigation system

Before developing your drip irrigation system, have the water tested to make sure that it is suitable for your crop and whether it contains soluble iron. Iron levels above 1 mg/L can cause problems. Iron bacteria in the water can turn the soluble ferrous iron into insoluble ferric iron that precipitates as a red sludge and will block the drip outlets. Chlorinating the water will kill the bacteria and prevent precipitation.

Filters

A good filtration system is essential because the drip outlets are very small. There are three main types of filters: sand filters, mesh and screen filters, and multi-media filters. The type of filter needed will depend on water quality. Talk to a reputable irrigation specialist before deciding on the type of filter you need.

Filters should be cleaned regularly, either manually or automatically. You should also flush out the pipes regularly; the dirtier the water the more often you need to do it. If flushing valves are fitted to the ends of drip tubing the system flushes automatically after each irrigation.

Chlorination

Chlorination is an effective way of cleaning and keeping drip tape clean by oxidising and destroying organic matter and micro-organisms. The quantity of chlorine required to oxidise these organisms is referred to as the chlorine demand of the water. The chlorine left after oxidisation is the residual chlorine, which can be measured at the end of the irrigation system using a swimming pool test kit. You should aim to have 1 mg/L (ppm) chlorine at the end of your system indicating you have used enough chlorine. The amount of chlorine required will depend on the quality of the water.

Chlorine is corrosive and toxic, so read the label carefully and handle it with care. It is available as liquid sodium hypochlorite, usually around 10 to 12.5% chlorine, or granular calcium hypochlorite, usually around 65 to 70% chlorine. Chlorination can be continuous, using 1 mg/L residual chlorine; on a regular basis at about 10 mg/L; or as a slug dose using 500 to 1000 mg/L. Test the water at the end of the system to ensure there is about 1 mg/L residual chlorine. When using chlorine regularly it is injected over the last 20 to 30 minutes of irrigation.

The slug dose is only used if the drip outlets are badly blocked or before used tape is to be reused. Chlorine at this concentration may damage plants. It is left in the system for 24 hours, then flushed out. First flush water out of the main lines, then the sub-mains and finally through the open ends of the drip tubing. If the mains and sub-mains are not flushed first, all the sediment cleaned from them will go into the drip lines.

Chlorine can be injected into the irrigation water on either the suction or the discharge side of the pump, but before the filter. The filter must be resistant to corrosion by chlorine. Make sure the pump runs long enough after you stop injecting chlorine to ensure that no chlorine is left in the pump or any other metal part of the system.

If your pumping rate is 500 L per minute, then each minute you will need to add the amount required for 500 L, for as long as it takes the water to reach the furthest point of your system. You can use a swimming pool test kit to determine when the chlorine has reached this point or put dye in the water.

Calculating how much chlorine to inject

To calculate how much chlorine to inject you need to know:

- the chlorine concentration of your chlorine product;
- the flow rate of your pump in litres per minute;
- how long it takes the water to reach the furthest point of your system.

Table 62 shows the amount of two chlorine products required to make two different concentrations of chlorine.

Table 62. Chlorine product required for two concentrations of chlorine

Concentration required	12.5% chlorine product		65% chlorine product	
	rate per 100 L	rate per 500 L	rate per 100 L	rate per 500 L
10 mg/L	8 mL	40 mL	1.5 g	7.5 g
500 mg/L	400 mL	2 L	75 g	375 g

An integrated approach to pest and disease management

Managing pests and diseases is probably the most difficult aspect of sweet corn growing. Serious pests and diseases will most likely be a problem at some stage in the life of the crop. These problems have the potential to reduce yield and quality and therefore profit. This section describes an integrated approach to pest and disease management which takes account of prevailing conditions and suggests more sustainable methods of sweet corn production.

Integrated Pest Management (IPM)—What is it?

The current approach to crop protection is to manage crop pests with a range of management options so that the pests do not cause economic damage. Crop pests can be insects, mites, diseases, weeds or even animals (birds, mice, kangaroos). An IPM strategy aims to reduce the pest population to a minimum using a range of tools and management options. IPM is also designed to maintain environmental sustainability and the economic viability of the production system.

An IPM program needs to be a part of the whole production system looking at the various components of the system and how they might be manipulated in order to reduce the pest population. As such, IPM is an integral component of Integrated Crop Management (ICM), where all aspects necessary to grow a crop are considered.

An integrated approach to pest management utilises a range of management options most suited to the crop, while at the same time reducing pests to acceptable levels. These control options could be a combination of cultural, physical, biological and chemical control measures to manage sweet corn pests and diseases.

Management options

Integrated Pest Management involves a combination of management options from the following lists.

Cultural and physical management practices

- planning;
- site preparation;
- farm hygiene;
- crop hygiene.

Crop monitoring

- what you will need when monitoring a crop;
- how to monitor sweet corn;
- pest and disease monitoring—what to look for.

Biological management options

- protecting and promoting naturally occurring beneficials;
- introducing beneficial insects;
- using biological insecticides—biopesticides.

Chemical management options

- mode of action;
- spectrum of activity;
- residual and persistent activity of chemicals;
- toxicity to beneficial insects;
- selection and timing of sprays;
- application equipment;
- responsible use of pesticides;
- resistance management strategies.

Cultural and physical management practices

Planning

Review the previous season. Review what happened last season and use this information to plan your actions for the current season. Think about:

- what did and didn't work;
- weather conditions during the crop;
- pest levels that occurred;
- your market, for example, export, local fresh market or processing;
- available products, changes in registrations;
- order beneficials, for example *Trichogramma*;
- review your monitoring logs, spray thresholds used last season and crop damage.

Site selection. Select a site that does not have a history of problems associated with growing sweet corn. Remember that:

- sequential plantings in close proximity may facilitate movement of pests between plantings;
- losses caused by nematodes are more likely in sandy soils but unusual in sweet corn, however root lesion nematodes can cause problems in north Queensland;
- frost and chilling damage are more likely in lower areas and where air flow is restricted.

Production methods. You may choose to grow your crop using drip, overhead or furrow irrigation. All of these methods can have an influence on pest and disease problems. Remember that:

- overhead irrigation can wash sprays off the plant, but may improve the performance of NPV;
- wind direction can influence disease spread but can also aid the dispersal of small parasitoids such as *Trichogramma*.

Production period. The time of year will influence what problems you have with your crop. Select a production period that will minimise pest and disease pressure. The production period for processing crops will usually be determined by the processor. Fresh market crops tend to be planted sequentially over the season to meet market requirements and ensure labour continuity. Remember that:

- foliage diseases are usually worse in warm, wet weather;
- heliothis are usually worse in warm weather;
- mites prefer warm, dry conditions.

Refer to the variety descriptions (page 136 to 140) for pest and/or disease tolerance or resistance, plant type and preferred conditions.

Crop varieties. The variety you choose will be determined by your time of production and known or expected problems.

Site preparation

Thorough land preparation is essential, particularly to allow for the complete break-down of crop residue and any green manure crop. Good land preparation will also assist with plant establishment by reducing the risk of waterlogging and plant losses from damping-off and other soil borne diseases and pests. Cultivation will help reduce the number of soil borne insects including over-wintering heliothis pupae, a process known as pupae busting.

more info
Management of heliothis page 188

Pupae busting. Mature heliothis larvae pupate in the soil and emerge as adults within two to three weeks. Heliothis also enter a stage of suspended development or diapause during the winter months, a process known as over-wintering. To control these pupae the soil should be cultivated to a depth of at least 5 to 10 cm. The pupae are either killed by direct physical damage or through disturbance of the emergence tunnel so the moth can't escape the ground.

Farm hygiene

Poor farm hygiene will result in losses from pests and diseases. Good farm hygiene is one of the simplest and most often overlooked methods of pest management. It results in fewer pests and diseases developing on and being spread around the farm. Good farm hygiene includes the following management practices.

Crop rotation. Sweet corn is a grass crop and can be planted after most broad leafed crops. French beans, tomatoes and capsicums have all been used successfully. Sweet corn is a good rotational crop with potatoes because the higher organic matter incorporated into the soil generally gives cleaner potatoes.

Most other vegetable crops can also be grown after sweet corn. However take care if sowing a vegetable crop after residual herbicides have been used. If a triazine herbicide has been applied to the sweet corn at the high rate, some vegetable crops should not be planted in the block for 18 months. Cucurbit crops are very susceptible to residual herbicides.

Cover cropping. Cover crops improve the soil's structure and its water and nutrient holding capacity.

Crop hygiene

Destroy old crops and their residues, weeds and volunteer (self set) plants that are a reservoir of pests and diseases. Plough in crops as soon as harvesting is completed, it could help reduce local area buildup of heliothis where sequential plantings are made beside each other.

Removal of reject cobs. Remove and destroy reject cobs that can be a source of disease infections such as boil smut. Heliothis infested cobs should also be destroyed by burying them to prevent larvae from pupating and developing into adults.

Good hygiene. Apply a high standard of hygiene and quarantine in the field and the packing shed. This should be part of your Quality Assurance system.

Crop monitoring

The books *Sweet Corn Insect Pests and their Natural Enemies*, a pocket book by Richard Llewellyn, and the companion book to this GROWING GUIDE, *PICTURE GUIDE: Sweet corn problem solver & beneficial identifier* will help. It is not necessary to immediately identify all the problems you find, but the more you can identify the better.

Monitoring sweet corn for pests and diseases is the first step in the crop protection cycle. Without monitoring you have no evidence of what pest management strategies need to be carried out or how well your current pest management strategies are working.

We recommend you use a competent crop consultant to monitor your crops. If you do not hire a professional crop consultant we suggest that you get some training from a crop consultant or your local departmental officer. There are a few procedures to follow in doing your own monitoring. Inspections should continue from emergence until harvest, and ideally start before planting to check for soil pests that may prevent uniform establishment. The intensity of monitoring will vary with the crop stage, pest pressures expected and weather conditions.

more info

Where to get these books
Chapter 5, page 253

What you will need when monitoring a crop

1. A note book or record sheets. A sample page that you can photocopy is on page 183, and a partly completed sample is on page 184.

Where to get traps and lures
Chapter 5, page 243

2. A 10 power hand lens. Most optometrists stock these or you can order them through an entomological supply agent. Magnifying glasses may also be helpful.
3. Plastic freezer bags to keep samples of unknown diseases for identification, as well as containers for collecting unidentified insects.
4. Pheromone traps contain a lure that attracts male heliothis moths. They can be a useful tool to detect large increases in moth numbers over time. There are two types of traps, the Texas (Scentry®) traps and pot traps, Figure 43. They are not a replacement for crop monitoring.
5. A means of identifying the more common problems and beneficials of sweet corn.

Figure 43. A heliothis pot trap, top and a Scentry trap lower

How to monitor sweet corn

1. Set aside enough time to check a block carefully.
2. Know what you are looking for in general terms before going into the block. The companion book, *PICTURE GUIDE: Sweet corn problem solver & beneficial identifier,* shows the symptoms and cause of most of the problems that you are likely to see.
3. Check each area or block regularly, twice a week during the seedling stage, at least once a week during the vegetative phase and twice a week during the tasselling and silking stages of the crop.
4. Check a good cross section of the block—pests can often be in patches or at one end or side of a block. Walk in a V, W or X-shaped pattern through the crop, starting at a different place each time you inspect the crop.
5. Before tasselling look at the whole plant. From the start of tasselling, concentrate on the tassels and then the silks from when they appear until they brown off, intensive monitoring is then no longer required. From the brown silk stage until harvest monitor for aphids, particularly if cobs are destined for the export market. See 'Pest and disease monitoring' below for details.
6. Write down what you find on a monitoring sheet or in a diary.
7. Simple tables and graphs of data help define patterns, and maps help identify local problems and pest movement.

Don't worry about not seeing a particular problem—you will.

Choose plants at random, being careful not to specifically target unhealthy plants while monitoring. If a plant doesn't look healthy and you don't know why, put it in a plastic bag and have the problem identified. Extension staff, local crop consultants or chemical resellers may be able to help with these identifications. A small 10 power hand lens assists with viewing small insects. Soon you will be skilled at identifying the range of pests, beneficials and diseases on your farm.

Pest and disease monitoring—what to look for

The following procedure is one of several that can be used for pest and disease monitoring, as indicated in ‘How to monitor a crop’.

1. Check overall appearance of the plants, paying attention to variations in colour and vigour. Closely inspect bleached and speckled leaves or yellowing patches for mite infestation, heavy disease infection or waterlogging of the soil.
2. Look for wilted or yellowing plants, particularly seedlings, and examine these for symptoms of disease or physical damage caused by soil insects.
3. Thoroughly examine a minimum of 20 to 30 plants per planting. In very large plantings you may need to sample several parts of the planting. The more plants you look at the more accurate will be your assessment of what is happening within the crop. A systematic sample may involve selecting a number of randomly spaced sites within the crop and assessing four to six plants at each site. The number of sites sampled will depend on the area of production and the time available for monitoring.
4. Carefully note and record the following information:

- The number and maturity of heliothis eggs on the leaves and stems, particularly the top third of the plant, tassels and/or silks and wrapper leaves of the cob. White eggs are newly laid, brown eggs will hatch in about one day, and shiny black eggs have been parasitised by a *Trichogramma* wasp. Check egg parasitism by collecting at least 20 brown eggs, more if possible, and waiting to see whether a grub emerges in about a day, or if they turn black, which usually takes a number of days.
- The number of other secondary pests such as armyworm, sorghum head caterpillar and yellow peach moth.
- Presence of thrips, aphids, mites and dried fruit beetles.
- What type and how many beneficial insects are present.
- The presence of any diseases, for example boil smut, leaf rust, viruses and wallaby ear.
- Weed types and stages of growth, and if they are harbouring insect pests or diseases.
- Record all observations on the monitoring sheet (see sample page 184).

Some of this information has been taken from the *Insect Pest Management in Sweet Corn*, HRDC project VG 97036 Milestone Report 5, Insect Scouting Protocols.
Where to get this:
Chapter 5, page 254

more info
Natural enemies
page 202

more info
Beneficial suppliers
Chapter 5, page 242

For major pests, enter the number of pests found in the monitoring log. For minor pests such as aphids, thrips and mites an approximate number is sufficient.

Biological management options

Biological agents (natural enemies, beneficials) can be used to help manage some insect pests of sweet corn, however growers cannot depend entirely on natural or released beneficial insects, particularly for heliothis control. Beneficial insects help reduce the pest population and include parasitoids, predatory insects and arthropods (spiders and predatory mites), fungi, bacteria, viruses, nematodes and animals, for example birds. Nature provides many beneficials (spiders and wasps) in our fields. Some beneficial insects (*Trichogramma*, lacewings and predatory mites) are reared commercially and can be released into the crop. Others are available as sprays, for example *Bacillus thuringiensis* and the nuclear polyhedrosis virus (for example Gemstar or Vivus).

There is a cost to using beneficials, but using them can reduce the cost of chemical applications and avoid the risk of pests developing resistance to the chemicals traditionally used. However, because of the high level of chemical application that can be necessary in fresh market sweet corn production, it is difficult to base your pest management solely on beneficial insects. If possible avoid using pesticides which may kill the beneficials, for more info see Table 68 on page 208. Suppliers of predators and parasites will also provide a list of chemicals that will not affect them.

Protecting and promoting naturally occurring beneficials

Beneficial insects which help manage pests, may be parasitoids or predators. If you use biological sprays, beneficial insect numbers in your crop and on your farm will gradually increase. This is particularly important at the start of the season when beneficial numbers are low. If you rely solely on organophosphates, carbamates and synthetic pyrethroids, beneficial numbers will remain low throughout the season and never be able to assist with pest control. Parasitoids, for example *Trichogramma*, are usually more sensitive to pesticides than are predators. Safeguarding this free work force requires the strategic and limited use of synthetic insecticides.

Beneficial insects supplement their diet with nectar and/or pollen, so some weeds or flowering plants planted within a crop may be beneficial. Weeds act as refuges for beneficial insects as well as harbouring some crop pests, such as aphids, that can supplement predatory beetle and lacewing diets and the aphid parasitoid.

Introducing beneficial insects

Only a small number of predators and parasitoids are reared by commercial producers. This is due to a lack of demand by growers and the cost of producing them. The most widely used beneficial insect in the sweet corn industry is *Trichogramma*, a heliothis egg parasitoid. *Trichogramma* has been very useful late in the season but numbers are usually very low at the start of the sweet corn season. The introduction of *Trichogramma* early in the season to supplement the natural population may be effective, provided softer biological pesticides are used. If IPM principles are followed, beneficial insect numbers should build-up with each successive sweet corn planting. Successive plantings benefit from the previous ones as beneficial insects move from one planting to the next in search of their prey, the insect pests.

Using biological insecticides—biopesticides

Most biopesticides are specific to a small range of pests. Non-target insects may become more abundant if biopesticides are used.

Bacillus thuringiensis (Bt)

Bacillus thuringiensis is a bacterial biological insecticide used to control a wide range of caterpillar pests, including heliothis, in sweet corn and other vegetable crops. Bt products are applied as a spray and the larvae need to eat enough of it to get a lethal dose. The bacterium is then activated by the larva's alkaline gut, producing a toxin which ruptures the gut wall causing the larva to stop feeding almost immediately. Table 63 shows some of the advantages and disadvantages of *B. thuringiensis* based products.

Table 63. Advantages and disadvantages of Bts

Advantages	Disadvantages
Only affects caterpillars, does not harm beneficials	May take some days before the larva is killed, though it will stop feeding well before that
Reduces the risk of resistance developing to other chemical controls	Short persistence, it is deactivated by sunlight
Soft on beneficial insects so is useful in IPM programs	

Nuclear Polyhedrosis Virus (NPV)

Nuclear polyhedrosis virus (for example Gemstar or Vivus) is an insect specific virus developed to control heliothis in a number of broadacre and vegetable crops. NPV will not control any grubs other than heliothis. Like Bt, NPV must be consumed by the larva for it to be killed. If the application is well timed the damage larvae do before they die is minimal. Use droppers for applications during silking to apply the product directly to the silks where it is most needed.

Smaller larvae are more susceptible than the older, larger larvae that will probably not be controlled by NPV. Late afternoon applications help prolong its effectiveness as it is rapidly degraded by sunlight. This product is exceptionally safe to both the environment and the worker. As it is specific to heliothis, beneficial insects are not affected by it, making it an ideal management option for an IPM program in sweet corn.

Practical experience indicates that NVP is far more effective when using overhead irrigating (for example centre pivots) than when irrigating by flood or drip. This is because overhead irrigation increases humidity and cools the foliage, creating a more suitable environment for the NVP virus to persist longer in the crop.

Spinosad

Spinosad (for example Success) is based on naturally produced metabolites of the soil micro-organism *Saccharopolyspora spinosa*. This product affects the insects nervous system producing a quick knockdown of most caterpillar pests, including heliothis, as well as some beetles and thrips.

Spinosad acts as both a contact and a stomach poison. Feeding ceases almost immediately and death occurs within three or more days, so take this into account when monitoring. Although spinosad is broken down in two to three days by UV light, its movement into the leaf results in the product having a longer residual effect. Spinosad has a relatively low toxicity to most beneficial insects, although it can adversely affect *Trichogramma* wasps, and has very little effect once it is dry. The above points make it useful in an IPM program.

Chemical management options

Mode of action

Chemical control usually refers to synthetically derived pesticides, including any toxic product that provides an immediate or short term kill of the pest(s). Pesticides are categorised as either non-systemic or systemic in their mode of action. Insecticides act as stomach poisons, contact poisons or fumigants, whereas fungicides act as either protectant or eradicant/curative products.

- **Non-systemic** pesticides are not absorbed by the plant and are only effective where they are applied.
- **Systemic** pesticides are translocated throughout the plant to where they are needed, often distant from the site where they were applied.

- **Translaminar** pesticides or semi-systemic pesticides can move from one side of the sprayed leaf to the other, where the pest may be protected from direct spray contact, as with mites and aphids.
- **Stomach poisons** need to be ingested by the insect in sufficient quantities for the pesticide to be effective. This may involve the insect chewing part of the plant with the pesticide on it, as with *Bacillus thuringiensis*, or by the insect sucking sap from the plant tissues, for example dimethoate, a systemic insecticide for aphid control.
- **Contact** pesticides need to come into direct contact with the pest, either by a direct hit, or by the pest walking over sprayed areas on the plant.
- **Fumigants** are used mostly for disinfesting soil of insects and soil borne diseases.
- **Protectant** pesticides, for example a fungicide that prevents the fungal spores from germinating and producing the disease, need to be applied to the entire plant surface before the disease arrives.
- **Eradicant or curative** fungicides destroy the plant disease after it has penetrated the host plant, by systemically moving into the plant tissue. Coverage is not as critical as with protectants, but good coverage will give better control.

Chemicals can be divided into a number of groupings, the main groups are: inorganics; synthetically derived organic molecules; and biologicals or botanicals.

Spectrum of activity

Spectrum of activity relates to the range of pests controlled by the particular pesticide. We will discuss only insecticides and miticides.

Broad spectrum insecticides control a wide range of insect pests and do not discriminate between beneficial insects and the insect pest being targeted. Synthetic pyrethroids (for example permethrin) and many organophosphates (for example dimethoate and chlorpyrifos) are examples of broad spectrum insecticides.

Narrow spectrum insecticides control a small group of insects. Examples are *Bacillus thuringiensis* on caterpillar pests, or chemicals specific to mites or aphids as with dicofol and pirimicarb respectively. Although developed to control caterpillar pests, some of the newer products, for example spinosad, will also have some activity on other pests. They are also relatively safe to a range of beneficial insects which is important in sweet corn IPM.

Residual and persistent activity of chemicals

Residual and persistent are two terms that can mean the same thing but are quite different when used to describe chemicals. Both the crop and the environment can be affected by the long term activity and persistence of chemicals.

Residual relates to how long the pesticide is still active or useful at controlling the targeted pest, whether that is a weed, disease or insect. Herbicides have the greatest residual effect in the soil and could determine the type of crop planted back into the treated area. High rates of atrazine may affect subsequent crops for up to two years, whereas metolachlor may be residual for only 10 weeks after the initial application. Insecticides generally have a short effective residual life on the targeted pests. Bts and viruses need to be reapplied after only a few days.

Persistent refers to how long pesticides remain in the environment. For some it's only a few days, for example insect viruses and *Bacillus thuringiensis*, for others it may be for several years, for example copper based fungicides and organochlorine insecticides. Although they persist, they do not necessarily have a direct effect on the targeted pest. Persistence is directly related to how the pesticides are broken down into harmless by-products by micro-organisms, enzymes, heat, moisture, ultra-violet light or cultivation.

Toxicity to beneficial insects

The implementation of IPM in sweet corn or other vegetable production systems has increased awareness of the effects that pesticides have on the beneficial insect populations within a crop. Beneficial insects are more susceptible than the insect pest to the wide range of pesticides used in horticulture. Table 68 page 208 shows how beneficial insects fare with pesticides used in sweet corn.

Selection and timing of sprays

Monitoring your crops gives you information on pest numbers and enables you to time spraying to prevent damage and spray when pests are most susceptible. Caterpillars are easier to control when they are small and feeding on exposed positions on the plant than when they are large and hidden within the cobs.

It is illegal to use a pesticide against an insect or disease problem for which it is not registered. Read the label carefully, it contains useful information on how to use that pesticide most effectively. The *Chemical Handy Guide* lists pesticides currently registered for use in sweet corn.

Application equipment

This issue is covered in *Pesticide application* on page 216.

Responsible use of pesticides

Use pesticides only when economically damaging numbers of pests are present and only apply pesticides registered for use in sweet corn. Always read the label before use, only apply the registered rates and observe the withholding period (WHP). The withholding period is the time between the last pesticide application and harvest.

If application rates are higher than those recommended on the label, or withholding periods are not observed, pesticide residues may exceed the maximum residue limit (MRL). Detection of residue levels above the MRL can lead to seizure of the produce and prosecution.

All chemicals are toxic to some degree, so follow safety instructions given on the label. Avoid spraying in hot, still weather or windy conditions when spray drift is likely. Always wear the recommended protective clothing as detailed on the product label.

An example spray record sheet is provided on page 182, and a partly completed sample spray record is shown on page 184.

Keep records

Commercial growers do not have to keep accurate records of all pesticides applied to their crop. However, there are several advantages in keeping such records.

- Records are useful for fine-tuning pest management practices, identifying problems and protecting growers against concerns with pesticide residues or spray drift.
- Growers implementing quality assurance systems may need to keep track of pest management decisions and practices.
- Requirements may change in the future and growers who are used to keeping records will find it easier to comply with any new legislation concerning pesticide use.

Resistance management strategies

Resistance to one or more pesticides has been a problem for a long time. Insects, diseases and weeds can all develop resistance to particular pesticides, for example heliothis has developed resistance to a wide range of carbamates and synthetic pyrethroids over the past two decades. When a new pesticide becomes available there is a tendency to use it until it fails due to heliothis or other pests developing resistance to it. As a result chemical companies are keen to promote resistance management strategies, either for a particular crop or a growing region. This helps safeguard the effectiveness of their product for longer so that it will control heliothis or other pests for a number of years.

Resistance management strategies are based on the principle of rotating products between chemical groups. Implementing time periods or windows during the year when new products use is restricted, can reduce the chance of pests becoming resistant to it.

Making a pest management decision

The first decision you must make is whether action, including pesticide application, is needed to avoid losses from pest damage. The management of pests in your crop depends on you making the right management action decisions. You should aim to:

- introduce parasites and predators (beneficial insects) if suitable ones are available;
- spray only when the pest level becomes economically damaging;
- spray at the stage in the pest life cycle when it is most susceptible;
- spray individual plantings and not the whole farm;
- target sprays on appropriate plant parts, for example the silks;
- use sprays that will be least damaging to beneficial insects.

Monitoring and action thresholds help you make these decisions. An action threshold is the critical level at which a decision is made. Below this threshold you maintain as many cultural practices as possible to reduce the pest's impact on your crop; above this threshold you start specific control measures targeted at the pest. Thresholds are based on the average number of pests found per plant.

$$\text{Average number of pests per plant} = \frac{\text{total number of pests recorded}}{\text{number of plants inspected}}$$

Thresholds for insect pests are generally based on pest numbers and stages of the life cycle found in the crop. They are intended to reflect the pest level that will cause economic damage. If pest pressure is high you may be over the threshold, if it is low you may not reach the threshold.

The threshold you set will also depend on the activity of beneficial insects and the risks involved in not controlling the pest. For example beneficial insects may build up rapidly with aphid populations and be more effective than chemicals.

For more detailed results see *Insect Pest Management in Sweet Corn*, HRDC Project VG 97036 Milestone Report 6, Best management Options.
Where to get this, Chapter 5, page 254

Weekly sampling for heliothis egg parasitism will indicate levels present within the crop and guide you in your choice of insecticides. A high percentage of black eggs indicates high parasitism levels reducing the need to take action against the pest. Without sampling for egg parasitism, or predator activity, you have no idea of the levels of beneficial insects present in the crop. Any sign of insect activity would most likely result in insecticides being applied whether they are needed or not. This can result in more damage to your crop, because you are also killing off beneficial insects which aid in the control of a number of insect pests found in sweet corn.

Threshold levels for other pests are normally based on the history of the area, stage of development of the crop, weather conditions and other observations. Record all these in your monitoring log, as they can be used to judge when outbreaks may occur and what steps may be required to keep them in check.

Using threshold levels

Broad thresholds developed by experienced crop monitors and researchers based in the Lockyer Valley in Queensland are presented, as a guide only, on page 181. No scientific research has established definite action threshold levels for sweet corn. With experience you may be able to refine these thresholds for your situation. Use these levels as a guide to when specific action should be taken. Higher pest levels may be able to be tolerated up to tasselling.

Use the **low** threshold figures when the crop is at a sensitive stage to that pest, for example silking, or at the start of the season when beneficial insects numbers have not yet built up.

Use the **high** threshold figures when the crop can tolerate the pest, or when beneficial insect numbers are high, generally later in the season.

Medium threshold figures should be used at other times.

Reviewing the variations recorded in pest levels is another guide to making the decision to act. For example if the number of brown eggs is much lower than the level of white eggs previously recorded, it is likely that there is a moderate to high level of predation occurring.

An increase in pest activity may indicate the need for:

- checking spray application equipment;
- a different pest control strategy;
- a different pesticide selection;
- an additional pest control strategy;
- a shorter spray interval.

A decrease in pest activity may indicate the need for:

- a longer spray interval;
- a softer pesticide selection;
- reduced targeting of that pest.

Once you have decided what pests need to be targeted you are ready to decide what control actions to use. The *Chemical Handy Guide* lists the pesticides registered for use in sweet corn.

more info
Variety descriptions
pages 136 to 140

Incorporate other strategies, in addition to pesticides, into your pest management plan. These include field hygiene and quarantine, biological control, resistant varieties and crop rotation. Using a range of pest management options in an integrated approach is called Integrated Pest Management (IPM). IPM generally reduces the risk of crop loss because it uses a broad range of options rather than relying on a single control option.

The following tables are based on crop monitoring experience in Queensland's Lockyer Valley, they are included only as a guide and may not be valid for other production areas. Table 64 is for the vegetative stage of the crop, from planting to tasselling and Table 65 is for the reproductive stage, tasselling to harvest.

Table 64. A guide to pest levels from planting to tasselling

Pest	Part of plant to check*	Record	Pest threshold to use		
			Low	Medium	High
Insects and mites			Average number per plant		
Heliothis	Whole plant	No. of eggs No. of larvae (vs/s)	1–5 1	5–10 2	10+ 3
Thrips	Whorl	Number	1–20	20–100	100+
Two-spotted mites	Lower leaves	Number	0–10	10–50	50 +
Aphids	Lower leaves	Nymphs + adults**	1–20	20–100	100 +
Leafhoppers	Whole plant	Nymphs + adults	No levels set, target young plants and control at first sign of wallaby ear		
Diseases					
Turcicum leaf spot	Leaves	Leaf area affected	No levels set		
Wallaby ear	Whole plant	Number of plants affected	Control leafhoppers at first sign of wallaby ear		

Table 65. A guide to pest levels from tasselling to harvest

Pest	Part of plant to check*	Record	Pest threshold to use		
			Low	Medium	High
Insects and mites			Average number per plant		
Heliothis	Tassels, silks, wrapper leaves and adjacent stalk	No. of eggs No. of larvae (vs/s)	0–0.1 0–0.05	0.2 0.2	1–2 0.25 +
Thrips	Silks and wrapper leaves	Number	1–10	10–50	50+
Two-spotted mites	Leaves adjacent to cobs	Number	1–10	10–50	50 +
Aphids	Tassels, cobs and leaves adjacent to cobs	Nymphs + adults**	As above for planting to tasselling or 2 tassels in 20 plants with aphids		
Diseases					
Turcicum leaf spot	Leaves	Leaf area affected	No levels set		

vs = very small, s = small; (see Figure 44, page 186)

*monitor 20-30 plants per planting or paddock; ** need to check for parasitism of aphids. Developed in association with Shane Gishford (Independent Crop Consultant Services) and Andrew Johanson (Mulgowie Farming)

Spray record

Business/Grower Name: .... Crop / Variety: .... Season /Year : ....

Date / time	Block / row	Crop stage / target	Product	Dilution rate	Application rate	Equipment used	Date safe to harvest / WHP	Comments (eg. weather)	Operator

To the best of my knowledge the information provided on this record is correct.

Name: .... **Signature:** .... **Date:** ....

Sweet corn pest, disease and beneficial monitoring log

Block: ______________________________ Date: ______________

Weather since last monitored: ______________________________

	Heliothis					Other pests eg aphids, armyworm, sorghum head caterpillar, thrips, yellow peach moth				Beneficial insects eg pirate bugs, ladybirds, lace wings, mirids, hover flies, predatory shield bugs				Others problems, eg diseases			Comments
Sample	White eggs	Brown eggs	Small larvae (less than 7 mm)	Medium larvae (7–23 mm)	Large larvae (more than 23 mm)					Black eggs				Turcicum leaf spot	Wallaby ear		
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
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19																	
20																	
21																	
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	
Total																	
Average																	

Overall comments and recommendations

SAMPLE spray record

Business/Grower Name: Bill Bloggs **Crop / Variety:** Sweet corn **Season /Year :** summer /2004

Date / time	Block / row	Crop stage / target	Product	Dilution rate	Application rate	Equipment used	Date safe to harvest / WHP	Comments (eg. weather)	Operator
23/1						Boom spray		Calibrated boom	B Bloggs
25/1	1	Tassels/heliothis	Gemstar	350 mL/ha	400 L water	Boom	N/A	Fine	B.B.
31/1						Boom/droppers		Calibrated boom with droppers	B.B.
1/2	1	Silks/heliothis	Success	400 mL/ha	450 L water	Boom/droppers	N/A	Cloudy	B.B.
5/2	1	Silks/heliothis	Methomyl	2 L/ha	450 L water	Boom/droppers	1	Fine	B.B.
10/2	1	Silks/heliothis	Success	600 mL/ha	450 L water	Boom/droppers	N/A	Cloudy	B.B.

To the best of my knowledge the information provided on this record is correct.

Name: ………………………………………………… **Signature:** ……………………………………… **Date:** ………………………….

SAMPLE sweet corn pest, disease & beneficial monitoring log

Block: A4, been silking for 3 days **Date:** 23/05/04

Weather since last monitored: Fine, may rain in next few days

	Heliothis					Other pests eg aphids, armyworm, sorghum head caterpillar, thrips, yellow peach moth				Beneficial insects eg pirate bugs, ladybirds, lace wings, mirids, hover flies, predatory shield bugs				Others problems, eg diseases			Comments
Sample	White eggs	Brown eggs	Small larvae (less than 4 mm)	Medium larvae (7–12 mm)	Large larvae (more than 12 mm)	Armyworm				Black eggs				Turcicum leaf spot	Wallaby ear		
1	1	-	-	-						1							
2	2	1	1														Aphids on lower leaves
3	0	0															
4	3	1															
5	2	2															
6	6	0								2							
7	0	0	3														
8	3	1															
9	2	0															
10	5	0															
11	0	1	2							1							
12	0	2															
13	1	0	1														
14	2	0															
15	4	0															
16	2	0															
17	3	1				1L											
18	2	1								1							
19	0	2															
20	0	1	1														
21	0	0															
22	1	0															
23	2	1								2							
24	4	1															
25	3	0															
26	2	0															
27	0	1															
28	1	0								1							
29	0	2															
30	3	3															
Total	53	21	8			1				8							
Average	1.8	0.7	0.3							0.3							

Overall comments and recommendations

Insect & mite pest management

Pest infestations are a major cause of reduced yield and quality in sweet corn. Monitoring for pests and managing them is critical to your success as a sweet corn grower. The main problem is heliothis, but other caterpillar pests such as armyworm, yellow peach moth and sorghum head caterpillar can also cause damage. Pests such as aphids, mites, thrips, green vegetable bug, dried fruit beetle and soil borne insects can also be problems at different times of the growing season or in different districts.

Heliothis

Specific monitoring advice for each state is presented in the Insect Pest Management in Sweet Corn, HRDC project VG 97036 *Milestone Report 5, Insect Scouting Protocols*. This report is available from the DPI Victoria website listed in Chapter 5 page 254

Heliothis grubs are the major insect pest of sweet corn. They are the larvae of *Helicoverpa armigera* moths and are also known as corn earworm and tomato grub. The larvae of *Helicoverpa punctigera* are called native budworms and do not attack sweet corn.

Heliothis caterpillars chew leaves or tunnel down the silk channel of the cob. In the cob they feed on the kernels, the bigger grubs do more damage. The presence of caterpillars and damaged kernels make the cob unfit for fresh market (whole cob) sale. Damage can be removed by topping and tailing the cobs and marketing them in pre-packs.

Heliothis will be present throughout the year, though they are more common in warmer months and less common in winter. In cold areas they are virtually absent in winter.

H. armigera is very uncommon in southern NSW and Victoria during winter. They pupate and go into diapause in late autumn and reappear in spring. Those moths present have generally emerged locally and have not travelled long distances. The *H. punctigera* moths do fly in from long distances but do not attack sweet corn.

In southern Victoria heliothis also emerge in spring and are active from early summer but pressure is generally highest from late summer through autumn while in northern Victoria pest pressure can increase earlier.

Eggs are laid singly on all parts of the plant. They are usually most abundant in the crop during silking when they are generally laid on the silks. The dome shaped eggs are about 0.4 mm in diameter, with ribs down the sides. They are white when freshly laid. As eggs age they turn from white to cream then develop a brown ring, which is the caterpillar developing inside. If the eggs turn black instead of brown, they have been parasitised, the black colour is the parasitic wasp developing inside. Eggs take two to four days to hatch in warm weather or up to 10 days in cool conditions. In southern NSW and Victoria eggs can usually hatch in five days during summer.

The Tasmanian climate is cool in comparison to most mainland production areas, so life cycles are at the longer end of the range indicated. Heliothis eggs will generally take 7 to 10 days to hatch during summer.

Caterpillars (larvae) go through six developmental stages before pupating. This takes about two to three weeks in summer, increasing to four to six weeks as conditions cool. Newly hatched caterpillars are less than 3 mm long and have a dark head and fine dark hairs along the body. Stripes appear on larger caterpillars whose colour varies from green to orange to brown. At the last developmental stage, caterpillars are 30 to 40 mm long. Figure 44 shows the approximate size of very small, small, medium and large heliothis caterpillars.

Age (days)	Instar	Length (mm)	Category
1	hatchling	1.5	
2	first	3	<3, very small
3	second	7	3–7, small
5	third	13	7–14, small/medium
8	fourth	23	14–23, medium/large
11	fifth	28	> 23, large
14	sixth	30+	

Figure 44. Approximate size of very small, small, medium and large heliothis larvae. Source: Lowan Turton, NSW Agriculture

Figure 45. Heliothis pupa, pupal chamber and exit hole

When the caterpillar has grown and is fully fed it moves from the plant to the soil. The caterpillar digs into the soil, makes a pupal chamber and an emergence tunnel and then turns into a pupa, Figure 45. Under normal conditions the pupa will form an adult moth and emerge from the soil after at least 16 days.

In early-mid autumn the heliothis pupa can enter a resting stage known as over-wintering, or diapause. An over-wintering pupa stays in the soil in a state of suspended development for several months before resuming development and emerging as a moth. Decreasing daylength (generally less than 12 hours) and low temperatures, less than about 23°C, trigger over-wintering. In south Queensland, NSW and Victoria it usually begins in mid-March.

The percentage of the population that enters diapause increases with latitude from very low in north Queensland to very high, probably 100%, in southern production areas.

Over-wintering pupae resume development in response to increasing temperatures during late winter and early spring. Seasonal conditions determine the exact timing of moth emergence. Under normal conditions moths begin emerging from late August in Queensland. The main over-wintering emergence begins in early November in southern NSW and October in Victoria.

This information is from the DPI&F CropLink leaflet, *Pupae busting*

In Tasmania, heat unit calculations suggest that heliothis can emerge from over-wintering by November but in practice most moths are immigrants from the mainland. *H. punctigera* moths appear as early as August while *H. armigera* first appear in November but peak in January.

Generally, in warm years, moth emergence will occur slightly earlier while in cooler years emergence will be delayed. Factors affecting soil temperature also influence moth emergence times. For example plant cover, such as weeds, may lower soil temperature and delay moth emergence.

Monitoring

Monitor crops frequently to help you make good management decisions. This should be at least once per week up until tasselling, then twice per week from tasselling to harvest. It is critical that you monitor your crop from the late vegetative stage.

During the vegetative stage check the leaves, whorl and stem. Once silking has commenced focus on the cob region, including the flag leaf, silks and some tassels. Monitor more frequently during the silking stage because once eggs have hatched the caterpillars quickly move into the cobs where management is difficult.

Pheromone traps provide additional information about heliothis pressure by indicating the flight activities of adult male heliothis moths. The male is attracted to the synthetic lure which imitates the female's sex pheromone. Pheromone lures are species specific, so a trap with a *H. armigera* pheromone should only catch *H. armigera* moths. In spring in Victoria, armyworms are sometimes also caught in these traps.

more info

Where to buy traps
Chapter 5
Contacts page 243

In Victoria, trials over several years have indicated that Texas (Scentry® traps), which are net traps, are an effective measure of moth activity but pot traps are not.

Pheromone traps cannot be used to determine when control measures are necessary, but do serve as an early warning system for migratory moths and indicate when to start checking the crop for eggs and young caterpillars. Inspect the traps at least twice a week during high risk periods and weekly in low risk periods, and record the number of heliothis moths caught. The trap catch indicates local pest pressures from field to field. Compare yearly catches to the previous seasons' records to indicate whether there is likely to be more or less pressure.

Monitoring for over-wintering pupae

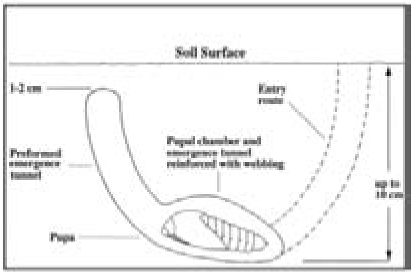

Figure 46. Drawing of a pupa in emergence tunnel

To monitor a field for over-wintering pupae, measure out a series of randomly selected one metre lengths of row and search for emergence tunnels. Carefully remove the top 2 to 3 cm of soil with a garden trowel and inspect for tunnels. Each emergence tunnel will appear as a small circular hole slightly larger in diameter than a pencil, see Figure 46. When the tunnels are found, dig carefully down to about 10 cm to find the pupae.

Soil moisture will influence the success of pupal sampling; soil too wet or too dry makes accurate sampling difficult. Sometimes the chamber will only contain the remains of the pupa indicating that the moth has emerged; in others the intact pupa will still be present. The pupae will be 2 to 10 cm deep depending on the soil conditions when the caterpillars move to the ground to pupate. If the soil is moist they will tunnel down further to construct their pupal chamber and emergence tunnel. Caterpillars seek a site to pupate where the soil is soft or well-drained, such as close to the plant row. Consider pupae busting if more than one pupa per 10 m^2 is found.

Management of heliothis

This information is from the DPI&F CropLink leaflet, *Pupae busting.*

Heliothis management will influence the management of many other pests. Biological control, chemical pesticides and 'pupae busting,' or a combination of these methods, can keep heliothis below damaging levels.

While biological agents may help in the management of heliothis, at certain times of the year pesticides are usually needed to attain a commercially acceptable standard of produce, especially for fresh market sale.

Many parasites and predators attack heliothis eggs and caterpillars. However they do not normally provide sufficient management where broad spectrum pesticides are used, or during unfavourable conditions, for example spring time in Queensland's Lockyer Valley.

Good heliothis management has been achieved without using pesticides during silking in systems where:

- biological pesticides are used;
- environmental conditions are suitable;
- parasites and predators have become established.

This scenario has been achieved by some growers in summer/autumn sweet corn crops in the Lockyer Valley.

Beneficial insects—*wasps*

Figure 47. A release site for a commercial pack of Trichogramma

Egg parasitoids, such as the *Trichogramma* and *Telenomus* wasps, occur naturally in most areas, except Tasmania, and can destroy many eggs. Parasitised eggs become black and shiny. *Trichogramma* sp. are also available commercially and can be released into crops, Figure 47, as a natural 'insecticide' to increase the proportion of parasitised eggs. However this technology is still experimental, so growers should be cautious. Releases of these wasps are useful when heliothis pressure is low or before cobs are produced. Parasitic wasps are susceptible to most chemical insecticides. Follow the supplier's instructions and treat the wasps carefully, they are delicate insects.

Bacillus thuringiensis (Bts)

Bacillus thuringiensis (Bt) is the active ingredient of a range of biological pesticides. It is effective against heliothis and other caterpillar pests. Good coverage is essential as the caterpillars must feed to obtain a lethal dose of Bt. Bts are most useful when heliothis pressure is low, or in the early stages of the crop. Aim applications at hatching eggs and young caterpillars.

Nuclear Polyhedrosis Virus (NPV)

The *Helicoverpa zea*, and recently *H. armigera*, strains of nuclear polyhedrosis virus have been formulated into commercial biopesticides. Some different strains can also occur naturally in the crop. NPV is very host specific to the heliothis larval stage. The caterpillars must eat the virus to become infected. Aim applications at hatching eggs and young caterpillars. Much larger doses are required to kill large caterpillars. Conditions of high humidity favour the effectiveness of NPV. Depending on the temperature, caterpillars may take about a week to die. Apply NPV during the vegetative stage because caterpillars in cobs will damage the kernels before they die. Vigilant monitoring is required for applications during silking.

Cultural

Over-wintering pupae may be killed by cultivation if the soil is fully disturbed. Cultivation to a depth of 5 to 10 cm with appropriate equipment either kills them by direct physical damage or through disruption of the emergence tunnel so the moth can't escape from the ground. This process is known as pupae busting. It is more commonly used in south Queensland and southern states than in central and northern areas.

Broad spectrum pesticides

Broad spectrum insecticides not only kill *H. armigera* but are also active against other pests and beneficial insects. *H. armigera* has developed resistance to a range of broad spectrum insecticides in several chemical groups, so these insecticides are no longer as effective. Even when *H. armigera* has developed resistance to a chemical, they are still susceptible in the very early instar stages, which is why timing sprays is so important. The *Chemical Handy Guide* lists chemicals registered to manage heliothis.

Some insecticides only kill caterpillars while others kill eggs and caterpillars. Good coverage is essential. Most eggs are laid on silks, so take particular care to get good coverage of this part of the plant. Correct timing of sprays is also important. Eggs and young caterpillars are much easier to kill than older caterpillars and do less damage.

Many of the older chemistry based pesticides may also kill the adult heliothis, the moth.

Armyworms

There are several species of armyworms, the larvae grow up to 35 mm long. They are difficult to separate and identify in the field, especially when the caterpillars are small. Armyworms are sporadic pests and do not always cause economic damage. They include the common armyworm, *Mythimna convecta,* northern armyworm, *Mythimna separata*, the dayfeeding armyworm, *Spodoptera exempta* and in Tasmania the southern armyworm *Persectania ewingii*, which occurs in spring and may cause some foliage damage. The common armyworm will chew and contaminate the silks.

Armyworm caterpillars can be confused with heliothis. Large caterpillars both have green and brown stripes, however large armyworm caterpillars appear smooth with fewer hairs than heliothis.

The common armyworm caterpillar is brown with dashed black stripes along the back and two wide pale stripes along the sides. The two back stripes continue towards the head as white lines bordered with black, then continue as black stripes over the head capsule. The head is stippled in black and brown. The common armyworm hides by day and feeds at night. Caterpillars lodge in the whorl where they feed on the new leaves. Older caterpillars are voracious feeders and as the crop develops they will attack silks and developing ears.

Common armyworm and northern armyworm caterpillars hatch from eggs laid in crevices, for example under the sheathing at the base of leaves. Caterpillars undergo a series of moults before reaching full size.

When mature, the armyworm caterpillars burrow into the soil to form pupae from which adult moths emerge. The moths are active at night. The life cycle can range from six weeks to several months depending on temperature.

Day feeding armyworm is important at times in northern Queensland where it occurs between late December and March. Outbreaks follow good rains after a drought period and appear to be more serious when the rains are late. Eggs are laid in clusters of a few to about 400 eggs by night flying moths. The clusters are covered with the fawn coloured hairs of the abdomen of the female and are normally found on the leaves of the young plants. Eggs hatch in about three days and the dark, striped caterpillars take about three weeks to mature. Leaves up to 450 mm from the ground are stripped. Damage to crops may not be noticed until the caterpillars are almost fully grown.

Monitoring

Armyworms commonly appear in the seedling and vegetative crop stages, particularly in the whorl and then the tassel as the crop matures. They are easier to see during the seedling stage than in the vegetative stage. Some feed at night making it difficult to identify the cause of the leaf damage and to monitor. Damage may not be noticed until the grubs are fully grown, when they may be difficult to kill. Feeding on silks may affect kernel set and detract from the appearance of fresh market cobs.

Management

Armyworm are rarely in sufficient numbers to warrant management action, unless in high numbers in the seedling stage. However as a caterpillar pest, their management is similar to heliothis. They are, however, more likely to be killed by older pesticide chemistries as armyworms do not have tolerance to pesticides.

Biological

Parasitic wasps and insect diseases (naturally occurring or via a commercial formulation) can play a significant role in armyworm management, often before the critical stage of the crop is reached.

The caterpillars are subject to fungal and viral disease, however these normally become widespread only when large populations of caterpillars occur and they act too late to prevent serious damage. The virus which attacks these caterpillars is different from the commercially available NPV, which is specific to heliothis. However Bts are not species specific and will kill armyworms.

In a low insecticide use environment the parasitic wasps, *Cotesia* spp. can be significant in armyworm control.

Broad spectrum pesticides

Be aware of the possible adverse side effects of broad spectrum pesticides. Spraying them in the early stages of the crop may delay the establishment within the crop of important beneficials such as *Trichogramma* wasps.

Aphids

The corn aphid *Rhopalosiphum maidis* grows to 2 mm long and is the most common aphid in sweet corn. Aphids spread Johnson grass mosaic virus.

Aphids can occur in sufficient numbers to damage plants by sucking sap causing wilting and leaf puckering. Their excretion or honeydew is sticky and hard to remove, and a black sooty mould grows on it, making cobs unattractive and unsaleable. It is a contaminant in export crops.

Monitoring

Monitor crops to ensure that aphids do not build up to levels that will cause economic damage. They first appear on the underside of lower leaves in the vegetative stage of the plant. Adults also fly into the whorl and spread through the top of the plant. Take action during this stage if there are high numbers. When aphids are in the cob wrapper leaves they are difficult to manage and it is usually too late to control them. When monitoring, especially during the vegetative stage, assess the activity of beneficials that attack aphids such as ladybirds, lacewings or parasitic wasps.

Management of aphids

Effective management includes good farm hygiene, beneficial insects and insecticides.

Hygiene

Destroy old crops as soon as harvesting is completed and destroy weeds that host aphids.

Beneficials

Natural predators of aphids include ladybird (coccinellid) beetles and their larvae, hover fly and lacewing larvae. Several species of parasitic wasps lay their eggs in aphids. A wasp larva develops within each aphid which dries and becomes swollen, tan/brown and mummified. An adult wasp emerges from the aphid mummy.

Beneficials can be effective in managing aphids, unless aphid numbers build up to high levels before the beneficials gain control. Minimise the use of broad spectrum pesticides to achieve the most effective biological control.

Pesticides

If necessary, spray to manage aphids with an appropriate chemical from the *Chemical Handy Guide*. Aim for thorough coverage of the undersides of leaves.

Maize leafhopper

The maize leafhopper, *Cicadulina bimaculata*, feeds by sucking sap. Adults are 3 mm long. In susceptible varieties the disorder wallaby ear occurs when heavy infestations, that is more than 15 leafhoppers per plant, inject a toxin into the plant while feeding. Significant damage is due to wallaby ear rather than direct feeding by the leafhopper.

Monitoring

Monitor crops carefully to ensure leafhopper numbers are not building up quickly.

Management of maize leafhopper

An IPM approach, including planting resistant varieties, farm hygiene and the use of pesticides when necessary, is the best way to manage maize leafhoppers.

Hygiene

If possible plant new crops well away and upwind from older infested crops. Destroy old crops immediately after harvesting.

Pesticides

If necessary spray with an appropriate chemical from the *Chemical Handy Guide*. When spraying it is important to get good coverage in the whorls of leaves.

Maize planthopper

The maize planthopper, *Peregrinus maidis*, is up to 4 mm long and feeds by sucking sap. It spreads the maize stripe virus.

Monitoring

Monitor crops carefully to ensure planthopper numbers are not building up quickly.

Management of maize planthopper

An IPM approach, including farm hygiene and the use of pesticides when necessary, is the best way to manage maize planthoppers.

Hygiene

If possible plant new crops well away and upwind from older infested crops. Destroy old crops immediately after harvesting and destroy volunteer maize, sorghum and wild sorghum plants.

Pesticides

If necessary spray with an appropriate chemical from the *Chemical Handy Guide*. When spraying it is important to get good coverage in the leaf whorls.

Thrips

A common thrips in Queensland sweet corn is *Frankliniella williamsi*. *Frankliniella schultzei* and other species have also been identified in sweet corn. Thrips are about 2 mm long and cause damage by rasping plant tissue in the whorl, under the leaf sheath or wrapper leaves or in the silks. They are rarely an economic problem through direct feeding, however damage to seedlings can be a problem. Thrips are a contaminant in cobs destined for the export market.

Monitoring

Thrips are present throughout the life of the crop, however their presence is most significant during cob development when they become contaminants. Monitoring the whorl and cob region before silk expression will provide an indicator to whether action is necessary.

Vigilant monitoring is important as it is highly likely thrips carried on the wind will reinfest the crop.

Management of thrips

Hygiene

Destroy old crops and weeds in and around the block.

Biological control

Predatory bugs, especially pirate bugs, *Orius* sp., can play a major role in managing thrips. However natural populations of these bugs do not decrease the population enough to reduce cob contamination so a combination of management options may be needed.

Pesticide

No narrow spectrum pesticides are registered in sweet corn for thrips management. Coverage and timing is extremely important, as this pest hides and can be difficult to reach. Target applications in the morning or afternoon, as thrips tend to withdraw into the leaf sheath and be least active in the middle of the day. If necessary apply an appropriate chemical from the *Chemical Handy Guide*.

Mites

Mites are usually more of a problem in warm dry conditions. Damage is usually caused by the two-spotted mite *Tetranychus urticae*, a spider mite that is about 0.5 mm long and infests a wide range of plants. All active stages cause a yellow stippling (bleaching) of the upper surface of the leaf and the sheath leaves around the cob, and a fine webbing underneath. They can be spread by wind and carried on clothing, machinery, birds and insects. Mites also make some workers itchy. Mites can affect the marketability of whole cobs for export, both as a contaminant and due to the discolouration of the sheath and flag leaves.

Monitoring

Monitor for mites by looking for the yellow stippling on the upper surface of leaves and checking the under surface for mites with your hand lens. They will often be near the main rib.

Management of mites

Mites can be very difficult to manage in warm, dry conditions. Monitor the crop and take action as early as possible to prevent a major flare up of mites. Hygiene, predators and miticides (if registered) are all options that should be considered.

Hygiene

Clean up old crops immediately after harvest and remove weeds and volunteer hosts from around the crop.

Predators

Predatory mites can be purchased to manage two-spotted mites, however many of the chemical pesticides used to manage other pests will also kill these predators. The companies supplying predatory mites will supply a list of chemicals that are least harmful to the predators. Releasing predators into the headlands around new plantings may help reduce mite numbers before they move into the crop. Some natural predators—adults and larvae of the ladybird *Stethorus* spp., lacewing larvae and predatory thrips—may also be present.

Miticides

Mites quickly develop resistance to some chemicals, particularly if the same miticide is used too regularly. Some chemicals, particularly pyrethroids, kill predators and can lead to a rapid build-up of mites. Good coverage of the underside of leaves is essential for the chemicals to be effective. The *Chemical Handy Guide* lists chemicals registered to manage mites.

Sorghum head caterpillar

Larvae, up to 13 mm long, of the moth *Cryptoblabes adoceta* can chew leaves as well as be contaminants in the silk and wrapper leaves of cobs.

Monitoring

Early stages in the life cycle are difficult to see, so start monitoring for this pest as silking begins. Look in the cob region, especially wrapper leaves and silks. More than one caterpillar may be found on an infested cob.

Sorghum head caterpillar is also a pest of field crops so neighbouring crops may be a source of infestation.

Management

Biological

When the biopesticide Bt is used against heliothis, it seems to provide some control of sorghum head caterpillar if coverage is good. There have been reports of *Trichogramma* parasitising the eggs. The parasitic wasp *Cotesia* sp. attacks the caterpillars, white bundles of cocoons beside dead grubs indicates their presence.

Broad spectrum pesticides

Applying pesticides can interfere with an integrated control strategy against heliothis. Before spraying, assess the economic significance of this pest compared with heliothis damage. If necessary apply an appropriate chemical from the *Chemical Handy Guide*.

Yellow peach moth

Conogethes punctiferalis, yellow peach moth, is a pest in Queensland. Caterpillars grow to 20 mm and tunnel into stems and the side of cobs and damage kernels. It is usually a minor pest but can do economic damage through feeding.

Monitoring

It is difficult to find the eggs and young caterpillars of this pest but monitoring should target the silking period and continue until close to harvest. Caterpillars are often found in the cobs but are also found between the cob and the plant stem. Frass and webbing may be found around the entrance hole.

Management

Biological

The biopesticide Bt seems to work providing coverage is good enough to reach the pest. There have been reports of *Trichogramma* parasitising the eggs.

The tachinid fly parasitoid is an important natural enemy in some crops. Pesticides will disrupt natural enemy activity.

Broad spectrum pesticides

Applying pesticides at the critical crop stage where this pest is found may destroy beneficials that control heliothis. The resulting heliothis damage is usually a more serious economic problem. If necessary apply an appropriate registered chemical from the *Chemical Handy Guide*.

Green vegetable bug

Green vegetable bugs (*Nezara viridula*) are a sporadic pest of sweet corn. They are more likely to be prevalent when alternative host crops such as soybeans are present in the vicinity.

Adults, 12 mm long, and nymphs will damage kernels by sucking the contents. The insertion point also provides access for secondary disease infection. They usually appear late in the crop during cob development.

Management

Management by pesticides is likely to upset a biological system in place for heliothis. Consider the pest management strategy for the whole crop before making any decision to spray. Weigh up the loss to green vegetable bug damage versus potential loss to heliothis if their management system is upset.

Parasites of green vegetable bug include several egg parasitoids, with *Trissolcus basalis* being the most common. There is also a parasite of the adult, *Trichopoda giacomellii*. These natural enemies have a more significant impact in managing green vegetable bug in sweet corn if the bugs are present early in the crops.

Dried fruit beetle

Dried fruit beetle, *Carpophilus* spp., are up to 4 mm long, and are especially evident after pollen starts to shed. They are often found around the leaf sheaths where pollen settles and then in the silks and developing cob. If harvesting is delayed the beetles enter the cobs, damaging kernels and contaminating the cob. Beetles are also attracted to fermenting cobs where cobs have been damaged.

Timely harvest usually avoids beetles being a problem as a contaminant. Management is not usually necessary.

Redshouldered (*Monolepta*) leaf beetle

Adult (6 mm long) redshouldered leaf beetles, *Monolepta australis*, move into the crop in swarms from spring to autumn and eat the leaves. They also chew on emerging silks which may affect pollination.

If crops are monitored regularly, spot spraying of the swarms with an appropriate chemical from the *Chemical Handy Guide* should be enough to manage this pest.

Soil borne insects

Cutworm

Several *Agrotis* species are minor sporadic pests during crop establishment as they cut off young plants at or near ground level. Larvae grow up to 40 mm long.

Monitoring

To determine the extent of the infestation it is usually necessary to dig in the soil to find the cutworm caterpillars. Inspecting the crop twice weekly in seedling and early vegetative stages will indicate whether there is a rapidly increasing proportion of crop damage that warrants management action.

Cultural

Remove weed growth for three to four weeks before planting the crop.

Broad spectrum pesticides

The *Chemical Handy Guide* lists chemicals registered for use in the early crop stage.

African black beetle

Adult African black beetle, *Heteronychus arator*, eat emerging plants at or just below ground level, eventually causing them to collapse and die. Infestations can arise from planting into poorly prepared infested land and/or adults walking or flying in from nearby pastures.

The beetle is glossy black, about 15 mm long and sluggish in its movements. It spends most of its time in or on the soil. The larva is a typical ‘C’ shaped white grub and grows up to 25 mm long. It lives in the soil and feeds on organic matter and grass roots. Adults are more likely to be causing damage than the larval stage because they are more mobile and are present for more of the year.

Monitoring
Check the crop at night for signs of activity and dig around in the soil for larvae or beetles. Grass pastures, especially kikuyu, are most likely to be infested with African black beetle.

Check areas before planting by grid sampling soil across the paddock with a spade, to a depth of 10 to 15 cm. By taking square samples you can get a count of beetle density, for example by taking 100 samples with a 15 cm wide spade the area sampled is 2.25 m^2. Divide the total number of beetles found by 2.25 to give the number of beetles per square metre. If it is around six control action should be considered.

Pitfall traps or sharp sided furrows can also be used to indicate pest presence. Furrows can indicate pest movement from adjacent areas. Marking areas and applying a drench with an insecticide can also be used to indicate pest presence. Invasions of flying beetles can be assessed by light traps or noting presence of insects around lights.

Management
Early detection of beetles allows early land preparation to remove pasture host plants, helping to disinfest the area before planting. There are no insecticides registered specifically for control of African black beetle in sweet corn.

Crickets
Crickets, including the black field cricket, *Teleogryllus commodus*, are minor and infrequent pests. Crickets feed at night and hide in the soil by day. They attack the newly planted seed and emerging seedlings by cutting off the tops and leaving them lying on the soil.

The field cricket is about 25 mm long and dark brown or black. Adults are winged and have strongly developed hind legs for jumping. Their presence is indicated by the noise the males make at night by rubbing their forewings.

Monitoring
Listen at dusk for cricket calls. Crickets are often present in March.

Management
Keep soil sufficiently irrigated to prevent excessive cracking which gives crickets easier access to exposed roots. Biological control agents including diseases, parasitoids, predatory birds and insects appear to have little effect.

Earwigs
Black field earwigs, *Nala lividipes* are 15 mm long and are minor and infrequent pests of sweet corn. They usually feed on decaying stubble

but also eat newly sown and germinating seed and the roots of crops. Feeding on prop roots may cause the plants to fall over as they grow. The damage is often first noticed when cultivating because the plants fall over as the equipment passes.

Monitoring

Take 300 mm X 300 mm soil samples down to the moist soil layer. The soil should be shaken onto a white sheet and if more than one earwig is found in 20 samples take management action.

Management

Black field earwig is a pest mainly in areas with heavy, black soils. They prefer cultivated soils to zero till. Use press wheels when planting to firm the soil around the seed. Prepare ground so that germination is as even and rapid as possible.

Wireworms and false wireworms

Wireworms, *Agrypnus variabilis* are the juvenile stage of click beetles and are about 20 mm long. Feeding by the adults and larvae (20 to 50 mm long) of false wireworms *Gonocephalum* spp. and *Pterohelaeus* spp. also reduces the uniformity of plant stands. The grubs are segmented, smooth, shiny and yellow to reddish brown. They are active in the root zone of seedlings in warm conditions but in hot weather move deeper into the soil.

Grubs tunnel into germinating seeds, feed on small roots of seedlings and bore into the base of plants below the ground and can then burrow up into the stalks. Seedlings wilt and usually die or are stunted and deformed.

As with other soil borne pests they are usually a minor sporadic pest. However wireworm can be a more serious pest in ground following grass pastures and grains in lightly cultivated soil. Usually by the time the problem is identified the damage is done. In susceptible areas inspect the ground before planting the sweet corn.

Management

Pre-planting treatment, treating seed and good soil preparation, can minimise the impact of this pest. They are difficult to manage once sweet corn is planted.

Ants and ground beetles are natural enemies of wireworms.

White grubs

Another sporadic pest, white grubs are the juvenile stage of scarab beetles, such as the Christmas beetle and related species, that are commonly attracted to lights. Most of the troublesome species have a two-year life cycle. Eggs are laid in the soil in spring and early summer. By the following winter grubs have passed through two of the three stages and move down through the soil sometimes to a depth of a couple of metres. During these stages they feed on soil organic matter

The maturing grubs prefer living plant tissue so they rise to the root zone where they can cause serious root damage, usually in the spring. Affected plants turn yellow, stop growing, wilt and die; they can easily be pulled out of the soil because no roots remain to anchor them.

The grubs are white with a brown head, 'C' shaped body and have three pairs of well developed legs. When fully grown they are about 50 mm long. Following rains in October-November beetles emerge from over wintering pupae in the ground. After mating, the females are attracted to friable soil, with high levels of organic matter, where they lay their eggs.

Species include: *Anoplognathus porosus*, *Lepidiota* spp., *Rhopaea magnicornis*, *Antitrogus mussoni* and *Repsimus aeneus*.

Management

Thorough pre-plant cultivation exposes grubs to birds and mechanically injures them so they die. Pre-plant incorporation of an appropriate registered insecticide is another option for managing this pest.

White grubs are difficult to manage once the crop is planted. Occasionally fungal diseases exert some control.

Natural enemies (beneficials)

Not all the 'insects' we see in sweet corn are doing damage to your crop. Many are in fact beneficials, natural enemies of the real pests damaging your crop. It is important to be able to recognise 'friend and foe', and take the necessary action. This section will help you make that identification. Coloured photographs of most of these beneficials can be found in the companion book, PICTURE GUIDE: Sweet Corn Problem Solver & Beneficial Identifier.

Introduction

Natural enemies or beneficial arthropods (insects, mites and spiders) help control pests in your crop. Avoiding the use of broad spectrum pesticides, using biological pesticides such as *Bacillus thuringiensis* (Bt) or Nuclear Polyhedrosis Virus (NPV) and introducing natural enemies into the crop all increase natural enemy activity.

Rarely do natural enemies alone achieve a standard of pest management sufficient to meet quality requirements for marketable produce. Therefore their role should be considered as part of an IPM system.

Natural enemies fall into two groups—parasitoids and predators.

Parasitoids

Parasitoids are organisms that parasitise and kill their hosts. The adults are free-living and are usually wasps or flies. The adult lays its eggs within or on the host pest at a critical life stage. The immature stage develops on or within the insect host, completing their entire development within that host by consuming it and eventually killing the host. Parasitoids tend to be very specific to their host, there are various wasp parasitoids that attack either moth eggs, aphids or caterpillars.

Egg parasitoids, such as *Trichogramma* spp. and *Telenomus* spp. may attack and develop in a range of moth eggs, typically turning the egg a silvery black. In comparison parasitised caterpillars show few external signs of parasitism before dying. The parasitoid larvae can sometimes be seen if the parasitised caterpillar is carefully pulled apart. Larval parasitoids include *Heteropelma,* several smaller brachonid wasps including *Cotesia* and *Microplitis,* and tachinid flies.

Aphids are often parasitised and are noticeable as bloated buff or brown shells commonly called 'mummies'. The aphid parasitoid, a small wasp, emerges through a circular hole in the abdomen of the aphid shell.

To determine the level of parasitoids in your crop you need to collect and rear the pests to observe if parasitoids will emerge from their host. Emergence could take from one to 50 days.

To increase parasitoids, protect those existing in your crop, also a limited number of parasitoids are mass reared by commercial producers and can be purchased. The most common is the egg parasitoid *Trichogramma pretiosum*, which has a wide host range.

Predators

Predators feed directly on their prey, they include insects such as predatory beetles; lacewings; predatory bugs; flies; predatory mites and spiders. Most predators are generalists, they attack a wide range of insects such as aphids, thrips, moth eggs, and small, medium and large grubs. Predators generally attack insects that are smaller than themselves.

Predators also supplement their diet with nectar, pollen and fungi. In most cases it is the larvae of these predators that are the main feeders and they tend to feed on the slower moving sap suckers including aphids, whiteflies and mites. Table 66 shows the relationships between natural enemies and pests found in sweet corn.

Table 66. Relationships between natural enemies and pests

	Beneficials (natural enemies)										
	Parasitoids							*Predators*			
Pest	Trichogramma	Telenomus	Microplitis	Heteropelma	Cotesia	Tachinid fly	Aphid parasitoid	Lacewings	Ladybirds	Predatory bugs	Spiders
Heliothis eggs	✓	✓							✓	✓	✓
Heliothis larvae			✓	✓	✓	✓			small	✓	✓
Armyworm					✓						
Sorghum head caterpillar					✓						
Aphids							✓	✓	✓	✓	✓
Thrips									some	✓	✓

✓ indicates host or prey of natural enemy

Enhancing effectiveness of beneficial insects

The following actions will help increase the effectiveness of beneficials.

1. Monitor crops to help reduce unnecessary insecticide usage;
2. Use pesticides (insecticides, miticides, fungicides) only when necessary;
3. Use an appropriate pesticide to control the pest and limit its direct impact on natural enemies (for example Bt sprays);
4. Provide an alternative food source for the adult parasitoids and predators (for example weeds or other flowering plants are a good source of nectar and pollen);
5. Make mass (inundative) releases of commercially reared beneficials, for example egg parasitoids and mite predators, so they become effective more quickly. Inundative releases have variable results. In some areas the introductions did have an effect and reduced damage. Releases over several years may result in establishment of populations of *Trichogramma pretiosum* and predatory mites in some areas.

Parasitoids and predators in sweet corn

Egg parasitoids

There are several species of egg parasitoids, the most common is *Trichogramma pretiosum* that is commercially reared. Depending on the season, other species such as *Trichogrammatoidea* spp. and *Telenomus* spp. also occur in sweet corn crops. The adult wasps are all minute, rarely visible when monitoring crops, however the black parasitised eggs can be spotted easily. There is little information on the presence of *Trichogramma* sp. and *Telenomus* spp. in Tasmania but they are considered to be either absent or uncommon.

The egg parasitoids can have a significant impact on heliothis populations if synthetic pesticides are not used. Their populations can be increased by releases.

Larval parasitoids

There are several parasitoids that attack the larva of some sweet corn pests, they include, *Microplitis*, braconid wasps and tachinid flies.

Microplitis

A parasitoid of heliothis and *Spodoptera* spp. *Microplitis* wasps are distinguishable by their brown pupae. They lay single eggs into young caterpillars. Their larva emerge, killing the caterpillar, and form a brown pupa lightly attached to the dead grub. There is little information on the presence of *Microplitis* in Tasmania but it is considered to be either absent or uncommon.

Braconid wasp

These parasitic wasps lay eggs into larvae of armyworm, heliothis and sorghum head caterpillar. The larvae emerge to pupate, forming white bundles of pupae on the outside of the caterpillar. The dead caterpillar may still be attached to the pupae. One of the common braconid wasps found in sweet corn is *Cotesia* sp.

These larval and aphid parasitoids are often brown or black and very small (<6 mm). They look like flying ants or tiny flies. From side on you can see a restricted 'waist'. Female wasps have a 'sting' at the tip of their abdomen, this is the ovipositor that inserts eggs into the host. Another distinguishing feature is that when they are walking on foliage you can often see their antennae quivering and tapping the foliage as they search for chemical traces left by hosts.

Tachinid flies

These parasitic flies are brown/grey/black and slightly bigger than a house fly. They lay a white oval egg on or near caterpillars. The fly larva enters the caterpillar and attaches to the skin, leaving a breathing hole. The maggot grows inside the caterpillar, eventually killing it. It then forms a brown, oval pupal case from which the fly emerges. Tachinid flies are not usually very common.

Predatory beetles

Predatory beetles include ladybirds, several species of which can be found in unsprayed sweet corn crops. The white-collared ladybird, *Hippodamia variegata*, is a recent introduction to Australia, and a voracious feeder on aphids. The majority of ladybirds are orange or red with a different number and shape of black spots. Their bodies are dome shaped with a hard wing covering. Their eggs and larvae are also prevalent especially when there are aphids present. Eggs are yellow, oval shaped and are laid upright on leaves, usually in a cluster. Larvae are black with coloured markings on the back. They also have three pairs of prominent legs.

Ladybirds are very effective predators of aphids but will also eat moth eggs and small larvae.

Predatory bugs

Pirate bug (Orius)

Pirate bugs are black and about 3 mm long. Their wings make a black and white cross pattern on their back. If thrips are present they are commonly seen where the leaves wrap around the stem or in the silks. The wingless nymphs are orange and black and go through several stages before becoming adults. Pirate bug eggs are white, oblong and are laid embedded in the leaf, often near the sheath. Pirate bugs are common predators of thrips but also feed on moth eggs, aphids and small caterpillars.

Black mirids

Black mirids move faster than pirate bugs and are larger and thinner than them. They have long antenna and do not have the cross pattern on their back. Their prey includes moth eggs and soft bodied insects.

Bigeyed bug

The bigeyed bug *Geocoris* spp. is about 4 to 5 mm long and is distinguishable by its large protruding black eyes. Its body is also black and squatter in shape than the pirate bug. Its prey includes aphids, mites, young caterpillars and moth eggs.

Damsel bug

The damsel bug is one of the larger predatory bugs, being up to 8 to 12 mm long. It is brown, long and thin, with large eyes and long antenna. Their prey includes soft bodied insects, moth eggs, small larvae and mites.

Lacewings

Brown and green lacewings are common in unsprayed sweet corn crops. Brown lacewing adults and larvae are predatory, especially on aphids. The adult brown lacewing has brown wings, larvae are also brown and eggs are laid singly on leaves. Green lacewing adults are not predatory; they have green wings and are slightly larger than brown lacewings. Their eggs are laid on stalks. Green lacewing larvae are predatory and carry debris from their victims on their back.

Spiders

Three types of spiders are commonly found in sweet corn crops—web spinners, foliage dwellers and soil dwellers. Wolf spiders are common soil predators, whereas the crab spiders, jumping spiders, orb weavers and many others are active predators in plant canopies. Their impact on pests has not been well documented however spiders represent up to a third of the predators recorded in sweet corn crops. They eat moth eggs, small caterpillars, aphids and thrips.

Predatory mites

Various predatory mites can occur naturally in unsprayed crops. *Phytoseiulus persimilis* is a predatory mite that can be bought commercially. Given the right environmental conditions it is a very effective predator of two-spotted mite. The mite is orange and the adult 1 mm long, larger than a two-spotted mite. Their body is pear shaped, appears smooth and almost dome like. Another distinguishing feature is that predatory mites move faster than two-spotted mites.

Minor natural enemies

There is a range of minor beneficials belonging to various groups including *Heteropelma*, hover flies, assassin bugs, predatory shield bugs, brown earwigs and pollen beetles (red and blue beetles). Pollen beetles are quite common in southern NSW.

The range and effectiveness of beneficials will vary between regions and may change from year to year in each region. The time of year when they are active may also vary. In most areas, *Trichogramma* wasps have far more impact on heliothis control than all other beneficials. Table 67 rates the efficacy of a range of beneficial insects and spiders in Queensland.

Table 67. The efficacy of a range of natural enemies

Common name	Scientific name	Beneficial rating*
Wasps and ants:	**Hymenoptera:**	**+++++**
Trichogramma	Trichogrammatidae	+++++
Black ants	*Iridomyrmex* sp.	++++
Microplitis	*Microplitis demolitor*	+++
Telenomus	*Telenomus* spp.	+++
Bugs:	**Hemiptera:**	**++++**
Black mirid	*Tytthus chinenis*	+++++
Pirate bug	*Orius* sp.	+++++
Apple dimpling bug	*Campylomma liebknechti*	++
Brown smudge bug	*Deraeocoris signatus*	++
Bigeyed bug	*Geocoris lubra*	+
Damsel bug	*Nabis kinbergii*	+
Spiders:	**Araneae:**	**+++**
Foliage dwellers (eg. jumping spiders)	Salticidae	++++
Soil dwellers (eg. wolf spider)	Lycosidae	+++
Web builders (eg. orb weaver)	Araneidae	++
Beetles:	**Coleoptera:**	**+++**
Ladybirds	Coccinellidae	+++
Carab beetle	Carabidae	++
Red and blue beetle	*Dicranolaius bellulus*	++
Green soldier beetle	*Chauliognathus pulchellus*	+
Lacewings:	**Neuroptera:**	**++**
Brown lacewing	*Micromus tasmaniae*	++
Green lacewing	*Mallada* spp.	++
Flies:	**Diptera:**	**++**
Tachinid flies	Tachinidae	++
Hover flies	Syrphidae	+

*Level of pest management in sweet corn = Low (+); Moderate (+++); High (+++++). Source: Scholz, B.C.G. (2000). Trichogramma and heliothis management in sweet corn: Developing an IPM package. *Doctor of Philosophy Thesis*, University of Queensland St Lucia, 260 page. P 206

Table 68 shows the impact of insecticides on pests and beneficials.

*Table 68. Impact of insecticides on pests and natural enemies**

Insecticides	Rating[1] of impact on natural enemies	Beneficial insects						
		Parasitic wasps		Predators				
Active ingredient	* = hardest **** = softest	Egg parasitoid *Trichogramma*	Larval parasitoids	Predatory beetles	Predatory bugs	Predatory mites	Lacewing	Spiders
Bacillus thuringiensis (Bt)	****	L	(VL)	VL	VL	L	(L)	VL
carbaryl	**	H	H	H	H	M	(M-H)	–
endosulfan	***	H	–	M	M	L	(M)	M
imidacloprid	**	(H)	–	H	H	(L)	(H)	VL
methomyl	*	H	H	VH	H	M	(H)	M
NP virus	****	VL	VL	VL	VL	L	VL	VL
organophosphates	*	(H)	H	H	H	M-H	(H)	H
propargite	***	L	L	L	L	L-M	M–L	M–L
spinosad	***	(M)	M	L	L	(L)	–	L
synthetic pyrethroids	*	H	VH	VH	VH	H	(H)	VH
thiodicarb	*	H	–	VH	M	(H)	(H)	L

Prepared by Bronwyn Walsh

1 Overall IPM rating: impact on parasitic wasps, predators, spectrum of pests; (% reduction in beneficials following application, based on scores for the major beneficial groups); VL (very low) less than 10%; L (low) 10 - 20%; M (moderate) 20 - 40%; H (high) 40 - 60%; VH (very high) › 60%. '–' indicates no data available; '()' estimated toxicity.
Ratings are based on research by Scholz (2001), Wilson, Holloway, Mensah and Murray (2001).

*Disclaimer: Information provided is based on the current best information available from research data. Users of these products should check the label for registration in their state, for rates, pest spectrum, safe handling and application.

Disease management

A range of diseases affect sweet corn but good management practices can minimise their effects. A key point to remember is that other Poaceae (grass family) crops, for example maize and sorghum, and weeds (for example Johnson grass), can also host some sweet corn diseases. Weed control and careful selection of rotational crops is of prime importance.

Seed-borne diseases

Seeds can carry some fungal diseases, such as *Fusarium* spp. or *Penicillium* spp. in sweet corn. These can lead to a symptom called early plant death, where plants are stunted, grow slowly and die when around 45 cm tall or less, resulting in an uneven plant stand. It can be made worse by low soil temperature, planting too deep early in the season or using old seed.

Management of seed-borne diseases

Only buy good quality seed treated with an appropriate seed dressing. Ensure soil temperatures are adequate and avoid planting too deep, especially early in the season when the soil is cool. Do a germination test before planting to check the health of the seed. To do this:

1. count out a number of seed, in tens, for example 100;
2. place them on a damp cloth or paper towel, cover them and place in a plastic bag;
3. hold them in a warm, not hot place;
4. keep them moist and after five days check the percentage germination;
5. keep checking for 10 to 14 days, or until no more seeds germinate;
6. look for signs of disease growth on the seeds.

Photos of disease symptoms in the companion *Picture guide: Sweet corn growers problem solver & beneficial identifier*

Soil-borne diseases

Soil-borne diseases are not generally a major problem in sweet corn. Outbreaks of soil-borne diseases can be expected in the same area year after year. The causal bacteria/fungi survive in soil for long periods and can be carried to new areas in contaminated soil on implements and with water wash. The first symptom is usually wilting due to damaged, inefficient root systems or girdled stems.

Management of soil-borne diseases

Maintain soil structure by incorporating green manure crops, but ensure they are decomposed before planting. Heavily compacted soils with poor structure, slow drainage and low aeration are prone to soil-borne disease problems. On heavy soils prone to waterlogging, hill up to increase soil depth and drainage.

Use an irrigation scheduling device such as tensiometers or a capacitance probe to ensure that plants are neither over watered causing waterlogging and low oxygen levels, nor stressed through under watering. Ensuring that plants are not over watered when they are young will encourage them to develop bigger root systems as they search for water, however plants should not be stressed.

Planting seed too deep puts the root system into soil that is often poorly aerated and predisposes plants to disease.

Do not use other crops in the grass family, for example sorghum, in rotation with sweet corn as the same soil-borne diseases also affect them.

If soil-borne diseases regularly occur, a fumigant, for example metham sodium, could be used as part of an integrated management program.

Nematodes

Some laboratories will test soil and root samples for nematodes. See testing laboratories Chapter 5 page 243

Nematodes are not normally a serious pest of sweet corn, however sweet corn can become infested with nematodes, particularly root lesion nematodes (*Pratylenchus zeae*). In north Queensland lesion nematodes have been associated with poor growth and stunting in the field. Damage by lesion nematodes can often be diagnosed by the presence of small blackish lesions on the root surface.

Lesion nematodes are most active at soil temperatures around 30°C. Secondary infections of damaged roots by fungi and bacteria often make it difficult to estimate the losses caused by lesion nematodes. Continuous cropping with sweet corn can contribute to a build-up of lesion nematodes in the soil. Sugar cane will also increase the numbers of *Pratylenchus zeae* resulting in damage if sweet corn is grown immediately after sugar cane.

Root-knot nematodes are more common on light sandy soils rather than heavy or compacted soils. Damage is more severe in warmer months. The root-knot nematode causes galls on roots that disrupt water and nutrient supply to the plant, leading to poor growth.

Crop rotation with non-host crops is the best long term management strategy for nematode control in sweet corn. Rotations with non-host crops or a fallow period of one year will reduce nematode populations. If your property has a history of root-knot nematode, a soil test will tell whether you should be using a nematicide. Recent research has shown organic mulches (sawdust, manure and sugar cane residues) suppress nematode activity.

Monitor for nematodes

Monitor the roots of broadleaf weeds before the final cultivation. Monitor for nematodes also at the end of a crop to give you an indication of the need for nematode control measures in your **next** crop. Serious damage is unlikely unless nematode levels are high.

A thorough sampling of a block at the end of the crop will provide more information than simply having soil analysed for nematodes before planting the next crop. Following is one technique that can be used for sampling for nematodes:

- Dig up plants from several areas of the block, taking care to retrieve the fine feeder roots. Carefully examine all roots for the presence of galls.
- The number and size of galls provide an indication of the degree of root-knot nematode infestation.

Foliar diseases

Photos of disease symptoms in the companion *Picture guide: Sweet corn growers problem solver & beneficial identifier*

The severity of leaf disease will vary markedly with weather conditions. There are two main fungal diseases affecting sweet corn leaves.

Common rust

Common rust is caused by the fungus *Puccinia sorghi*. Round to elongate, reddish-brown pustules develop on the upper and lower leaf surfaces. Pustules are up to 2 mm long and are scattered in groups over the surface. Leaf spots occur when tissue dies around clusters of pustules.

The fungus survives on diseased sweet corn or maize residues and volunteer plants. Large numbers of spores are produced in the pustules and are spread by wind over long distances. Warm, humid weather favours leaf infection, disease development and spore production.

Common rust is a common but usually minor disease. It generally appears after tasselling and does not become severe until kernel filling is complete. However, if warm, wet weather occurs during the kernel filling period, yield may be reduced. Late-planted crops are more likely to develop serious disease during the kernel filling period. Some supersweet varieties are highly susceptible.

Destroy volunteer maize and sweet corn plants before sowing. Early planting avoids high disease levels. Plant resistant hybrids late in the season when the disease is likely to be serious.

Turcicum leaf blight

Caused by the fungus *Exserohilum turcicum*. It is also known as northern corn leaf blight (NCLB) and northern leaf blight (NLB). Long, spindle-shaped, greyish-green, water-soaked spots generally develop first on the lower leaves. The spots or lesions turn grey and often exceed 100 mm in length. When weather conditions favour the disease, large areas of leaves are blighted. In moist weather, dark masses of spores cover the lesions. The fungus survives on maize and sweet corn crop residues and volunteer plants. Spores are spread by wind and rain. Warm, wet weather favours the disease.

Turcicum leaf blight is a common disease in sweet corn. Severe blight before or during tasselling reduces cob fill and yield.

Plant resistant hybrids, destroy volunteer plants and crop residues before sowing. Early planting usually avoids high disease levels.

Management of foliar diseases

more info

Varieties, page 135
Use appropriate chemicals from the *Chemical Handy Guide*.

Old crops and crop residues can provide inoculum for most foliar diseases. Good farm hygiene, including destruction of old crops immediately after harvest, and control of weeds in a wide margin around the crop, is sound practice. Plant resistant hybrids if they are available.

Diseases caused by viruses

The most common virus diseases of sweet corn are Johnson grass mosaic virus (JGMV) previously known as mosaic, and maize stripe disease caused by maize stripe virus.

Virus diseases are spread with plant sap. Aphids spread JGMV as they feed. Maize stripe disease is spread by the maize planthopper, *Peregrinus maidis*. The viruses also occur in maize and sorghum crops and weeds. These viruses are not transferred mechanically by plant-to-plant contact.

Wallaby ear was thought to be caused by a virus but is now known to be caused by a toxin injected during feeding by the maize leafhopper, *Cicadulina bimaculata*.

Management of virus diseases

Good farm hygiene, including destruction of old crops immediately after harvest and control of weeds and vectors in a wide margin around the crop, is sound practice. Spray to control aphids and planthoppers with appropriate chemicals from the *Chemical Handy Guide*.

Cob diseases

Boil smut

Boil smut is caused by the fungus *Ustilago zeae*. It affects maize, sweet corn and teosinte (*Zea mexicana*). The fungus attacks any actively growing, above-ground part of the plant and forms swellings referred to as boils, blisters or galls. These are most common on cobs, stems (even at ground level) and tassels, but also develop on leaves. Mature galls, which are up to 200 mm in diameter, rupture to release the spores. The spores are spread by wind, with seed or stock food, and in soil adhering to clothes, vehicles, farm machinery and animals, and may survive in the soil for many years.

Boil smut was first recognised in Queensland in 1982 and now occurs in most areas of the state. It also occurs in NSW. Occurrence is usually sporadic and minor, however high incidences can occasionally occur in sweet corn and maize crops.

Management of boil smut

Before planting ensure seed is treated with an appropriate chemical from the *Chemical Handy Guide*. Specific control measures are not warranted for field infections. Burning the stubble will reduce the number of spores surviving in crop residues and minimise disease carryover in the following year. Most hybrids have at least a reasonable level of resistance to boil smut.

Fusarium cob rot

Cob rot can be caused by various species of fusarium including *Fusarium verticillioides* (previously *F. moniliforme*). The main symptoms of this disease are rotting of entire cobs or scattered kernels within the cob. Fusarium infection produces a white-to-pink or salmon coloured mould that can be seen on the infected kernel surface. Cob rots develop either through infection of the silks by spores or the symptomless growth of the fungus through the plant. Insects may also play a role by damaging kernels and thus allowing the fungus to enter the cob.

Often only a small percentage of the cob will be affected, but when the infection is severe it may mean total crop losses. The environmental conditions that favour disease development are warm, wet weather two to three weeks after silking.

Management of Fusarium cob rot

Control options for Fusarium cob rot are limited. Planting hybrids that have shown previous resistance to cob rot may help. Some resistance is found in those hybrids with long husks that tightly enclose the silk channel opening of the ears. Husks that prevent or delay entrance of insects are partly responsible for resistance to cob rot. Early plantings usually have a greater chance of avoiding the disease.

Disease control program checklist

The following is a checklist of disease management strategies aimed at reducing yield losses and profit in sweet corn production.

Pre-planting

- ❑ All old crops on farm turned in.
- ❑ All crop residues rotted down in proposed field.
- ❑ Pre-planting fumigation if previous history indicates fumigation may be necessary.
- ❑ Virus weed hosts destroyed.
- ❑ Spray gear checked (new nozzles) and calibrated.
- ❑ The variety selected has resistance to diseases present, for example common rust and turcicum leaf spot.
- ❑ The seed has been treated.
- ❑ A germination test has been done.

Establishment

- ❑ Monitor for planting losses.

Early growth

- ❑ Be prepared to start a spray program.
- ❑ Monitor for foliar diseases and insect virus vectors.
- ❑ Monitor fertiliser and irrigation for steady crop growth.

Tasselling and silking

- ❑ Increase surveillance of foliar diseases and reduce spray interval in wet conditions.
- ❑ Maintain steady crop growth.
- ❑ Monitor for insect vectors of virus diseases.

Harvesting

- ☐ Maintain foliar disease control program, paying careful attention to the chemical withholding period.
- ☐ Monitor for postharvest problems.

Crop end

- ☐ Check roots for signs of nematodes.
- ☐ Plough in.

Seed treatment

Before planting ensure that seed has been treated with a fungicide, or use an appropriate chemical from the *Chemical Handy Guide*.

Shed hygiene

Clean shed equipment, cold rooms and picking equipment regularly to reduce the chance of disease infection from these sources. Chlorine solutions are effective but corrode metal equipment and some rubber compounds. Quaternary ammonia compounds are also effective and non-corrosive.

Principles of spray application

To ensure good pest control the pesticide must be applied correctly. To achieve good plant and target coverage by pesticides it is important that the spray equipment being used is correctly set up and calibrated accurately. It will then apply the correct amount of chemical, where it is needed, in the correct droplet size. Sprays will fail if not correctly applied. It is also important that the water used is of suitable quality and the chemicals applied are compatible.

Introduction

The objective of spray application in sweet corn is:

To control pests, diseases or weeds by the efficient deposition of the active ingredient onto the target in order to achieve market quality produce.

Efficient deposition means uniform droplet distribution on target surfaces with minimum losses due to drift, evaporation or run-off. In sweet corn production the target for disease control is the plant and/or the surrounding soil while for insect control the target is the plant, mainly the tassel and cob. For weed control the target can be either bare soil or the weed foliage.

Essentials of good spray application

Essentials to good spray application are listed below:

- hitting the target;
- good timing;
- suitable droplet size;
- suitable water volume;
- sufficient coverage;
- appropriate environmental conditions;
- using label rates;
- clean water;
- accurate pest and disease identification;
- appropriate spraying equipment;
- correctly calibrated equipment.

The target

The target varies depending on the growth stage of the plant. It changes from leaves, to tassels, to silks or even the actual pest. The aim of growing sweet corn is to produce cobs with minimal pest damage and free of live pests. Once insects entrench themselves in the tips of cobs they are impossible to control, therefore it is important to control insect pests early when they are exposed on the silks.

Other growth stages such as seedling emergence, the vegetative growth stage and tassel emergence may be equally important in certain production regions.

Spray deposit uniformity and distribution will influence the ability of pesticides to effectively control insect pests. There are several issues which influence spray uniformity and distribution:

1. crop canopy;
2. cob position;
3. application equipment.

Crop canopy

The crop canopy has a large influence on spray penetration and distribution on the plant. Distribution is very difficult to manipulate when spraying over the top with a boom because the deposit is highest in the top part of the canopy and reduces rapidly as you move down the plant.

Cob position

Unfortunately the cob is a long way down in the canopy and a large proportion of the spray volume will be filtered out by leaves before reaching the cob.

Some sweet corn varieties have large flag leaves surrounding the tops of cobs, others produce more tillers. There is also significant variation in canopy height of sweet corn varieties. All these factors have an impact on the spray efficiency especially when there is additional foliage sheltering the silk or a greater distance for droplets to travel before they reach the silk.

Selecting the type of sprayer

To be effective it is essential that the equipment used is able to efficiently apply chemical to the target. The ability to do this depends on many factors including the type of equipment, droplet production, droplet size, amount of water applied, water quality and spray drift.

Table 69 lists several important factors that should be considered when comparing various spray equipment types. The more ticks (✔), the more suitable or efficient that type of equipment will be in that situation.

When interpreting Table 69, a grower or operator who ranks achieving good spray penetration as very important, would be seeking equipment capable of directing spray onto the target zone to improve pest control. Penetration of the canopy when applying the pesticide to the target site is the critical factor when deciding the preferred method of application. With a high clearance sprayer crop height is less of a factor.

Table 69. Advantages of different types of equipment

	Standard boom	Air-assisted boom	Boom + droppers	Aircraft
Penetration	✓	✓✓✓	✓✓✓✓	
Timing (work rate)				✓✓✓✓
All weather access				✓✓✓✓
Crop lodging	✓✓✓✓	✓✓✓✓		✓✓✓✓
Crop height	✓	✓	✓	✓✓✓✓
Labour input				✓✓✓

Aircraft

Aircraft are used to apply pesticides in many sweet corn production areas in Australia. Using the comparison table above, aircraft application scores well because of short application time and all weather access. It receives the greatest number of ticks in most categories.

The types of nozzles used by aircraft are either hydraulic or controlled droplet application (CDA) nozzles.

Ground based sprayers

The following types of ground rigs are used to apply pesticides to sweet corn using hydraulic nozzles.

- conventional booms;
- conventional booms with droppers;
- air-assisted booms.

Conventional boom

Conventional hydraulic nozzles are spaced 500 mm apart on a boom sprayer. The best results are achieved when spraying in a light breeze at about 7 kph. The wind is beneficial because it creates turbulence to assist carrying the droplets into the crop canopy. At lower wind speeds the droplets will fall under gravity and there will be little or no redistribution of droplets deeper into the crop canopy. At higher wind speeds there is likely to be some drift.

Conventional boom with droppers

The performance of a conventional hydraulic nozzle boom sprayer can be improved by the addition of droppers. These are short lengths of semi-rigid plastic tubes attached to the boom with nozzles at the lower end.

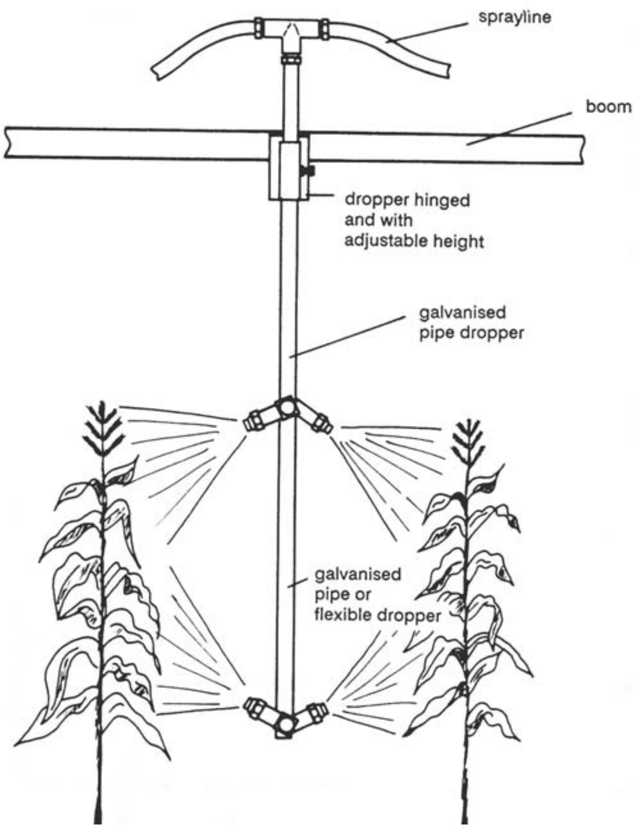

Figure 48. *Droppers to improve coverage on silks.*
Source: Pesticide Application Manual

They are positioned between plants to direct spray from a lower angle, increasing spray penetration and coverage. Figure 48 is a diagram of a dropper on a boom.

Air assist boom

Usually this sprayer is a conventional hydraulic nozzle boom sprayer with the addition of a high volume output fan mounted centrally above the boom with an air duct extending the full length of the boom. The slotted outlet of the air duct produces a curtain of air adjacent to the spray nozzles. This air curtain directs the spray down into the crop canopy causing agitation of the plants and improves spray coverage on both sides of the leaves.

Some recent versions of air assisted booms allow the option of angling the direction of the air stream either forward or backward to improve coverage.

CDA sprayers

Controlled Droplet Application (CDA) is a method of spray application where 80% of all droplets produced are within a very narrow size range, usually about 100 to 150 microns (µm).

Most CDA sprayers incorporate air assist as part of their design. The air stream directs spray down into the plant canopy causing turbulence that assists in achieving better overall coverage. These sprayers are another example of air assisted sprayer.

Some CDA sprayers have shrouds to help reduce drift and improve target coverage. They operate without any air assist and droplet size is in the 100 to 150 µm range. As long as the skirt around the shroud forms a seal with the ground, droplets within the shroud are not subject to external wind forces and fall onto the target by gravity. Typical application rates are around 45 L/ha for a single head with a swath width from 0.6 to 1.2 m.

Selecting hydraulic nozzles

Correct nozzle selection is very important in achieving the desired droplet range. The size and number of droplets produced has a critical influence on the coverage achieved. Table 70 shows a range of nozzle types, their spray angle, droplet size and pressure required.

Table 70. Nozzle types and some performance features

Nozzle type	Spray angle	Droplet size	Pressure
Conventional flat fan	80° – 110°	fine to medium	1 – 4 bars
Pre-orifice flat fan	80° – 110°	medium to coarse	2 – 4 bars
Flood jet	150°	medium to coarse	1 – 6 bars
Air inclusion	110°	coarse	5 – 6 bars
Hollow cone	80°	fine	5 – 10 bars

Note: This is only a guide and not a complete list. Nozzles give a range of droplet sizes that varies with spray pressure. A complete list and accurate technical data can be obtained from manufacture's nozzle charts.

How droplets are produced

Sprayers used in agriculture produce droplets by one of three methods:

- A hydraulic nozzle produces droplets when liquid is forced through a small orifice under pressure. These nozzles can be used on conventional booms and aircraft.
- A controlled droplet applicator for example rotating cage, inverted cone or a flat serrated disc produces droplets by means of centrifugal force when liquid is introduced at the centre of the rotating element. These nozzles can be used on both ground rigs and aircraft.
- Droplets can be produced by air shear when liquid is metered into a very high velocity air stream. These nozzles are only used on aircraft.

Droplet size

Droplets are usually measured in microns (µm), one micron equals 0.001 mm. All hydraulic nozzles produce a range of droplet sizes, this is called the 'droplet spectrum'. Droplets produced by a single nozzle can vary from 50 to 600 µm at any fixed pressure.

The most common way to classify spray droplets is by the Volume Median Diameter (VMD) which is defined as that droplet diameter which divides any given sample of spray droplets into two equal parts by volume.

Nozzles are classified by the British Crop Protection Council (BCPC) according to the type of droplet spectrum they produce, Table 71. These classifications are included in most nozzle catalogues and are a useful guide for assessing the drift potential and suitability of a nozzle for a given spray job.

Under this classification the International Standard Orifice (ISO) is used by all companies so that nozzle colour matches flow rate and droplet size for all nozzles at a given pressure.

Table 71. Droplet size categories

BCPC	Category	Approximate VMD range
VF	very fine	less than 150 microns

F	fine	150 – 250 microns
M	medium	250 – 350 microns
C	coarse	350 – 450 microns
VC	very coarse	450 – 550 microns
EC	extremely coarse	more than 550 microns

The most common droplet sizes used in agriculture are very fine (<150 µm), fine (150 – 250 µm), medium (250 – 350 µm) and coarse (350 – 450 µm).

Droplet spectrums with fine and medium droplets are most commonly recommended when targeting plants, including the cobs. This is a trade off between biological efficacy and reducing spray drift. When targeting the soil with pre-emergent herbicides larger, coarse droplets are more suitable because they are less likely to drift.

Not only do droplets need to be uniformly distributed over the target area, but their density on the target must also be sufficient to achieve good results. For insecticides, systemic fungicides and herbicides, the suggested droplet density is 20 to 30 droplets/cm^2. A higher density of 50 to 70 droplets/cm^2 is recommended for protectant fungicides.

What's wrong with large droplets?

- Fewer droplets are produced. One 400 µm diameter droplet has the same volume as 64 droplets with a 100 µm diameter.
- Fewer droplets mean there is less likelihood of the pesticide reaching the target organism.
- Large droplets are more difficult to retain on the leaf surface. They tend to bounce or roll off down the foliage and onto the ground.
- Large droplets are heavier and reach the target due to gravity. They are not usually deflected by air movement, so their redistribution within the crop foliage is limited.

Quantity of water applied (water rate)

The amount of water applied and the droplet size helps determine droplet density. Low water rates cause insufficient droplet density and poor coverage. High water rates result in plants dripping with excess pesticide and environmental pollution.

Good spray application aims to use a water rate that gives a uniform droplet distribution at the desired density. Research in sweet corn has found that water rates of 300 to 600 L/ha is best for ground rigs, and for aircraft 40 to 60 L/ha produces good coverage and control.

Checking spray coverage in the field

There are two main ways of checking spray coverage in the field, ultra violet lights and water sensitive cards.

Ultra violet lights

Spray a fluorescent dye, in water, at the normal pesticide application rate. You then use a special ultra violet light to look at the dye deposits on the crop in the field after dark. This illuminates the spray droplets and shows how the spray has been distributed on the plant. You can see if you are getting adequate coverage on the upper and lower leaf surfaces and silks.

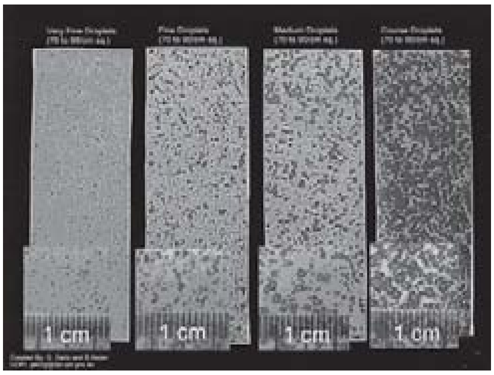

Figure 49. *Different droplet sizes on water sensitive cards*

Water sensitive cards

These cards are coated with a material that changes colour from yellow to bluish purple when moisture is present. They are attached to the top and underneath of leaves with staples. After the area has been sprayed inspect the cards for coverage. Droplet density can be estimated by comparing against standard cards with a known density, Figure 49. Another method is to place a card with a 1 cm^2 cut-out window on the water sensitive card, then use a hand lens to count the droplet stains.

Other influences on pesticide effectiveness

There are other factors that influence the effectiveness of pesticides. They include water quality and pesticide compatibility.

Water quality

The quality of water available on farms is highly variable and water from some sources can cause important application and effectiveness problems. Ideally, water should be clear, colourless, odourless and neutral (pH 7.0), that is, not acid, alkaline or brackish. Use the spray as soon as possible after mixing. If left standing for lengthy periods, undesirable interactions can occur between the water and some pesticides. To avoid unnecessary delays make all equipment checks and calibrations before mixing the pesticide.

Where possible, select water for the following characteristics.

Low total solids. Some disadvantages of using dirty water, such as causing blocked nozzles, are obvious. However, solids may also bind to pesticide chemical molecules and remove them from the spray mixture as sediment. Suspended clay minerals are a common problem in spray water and reduce the efficacy of some chemicals.

Neutral pH. Acid or alkaline water may hydrolyse pesticides (cause them to decompose). Additives are available to neutralise water if you cannot avoid using high alkaline or acid water.

High salt levels. Excessive salt content in water, can cause phytotoxicity (damage to plant tissue, for example burning). This is most common with bore water. It can also affect the pesticides being used.

Water 'hardness'. 'Hard' water containing calcium or magnesium salts may cause problems with mixing because it reduces the stability of suspensions and emulsions. Difficulty producing a lather with soap indicates hard water. Many pesticide formulations make allowance for water hardness, by having buffer agents in their formulation.

How to check water suitability

Use the following procedure to get a quick guide to the suitability of water for spray application:

1. Make up, in a stoppered clear glass container, 500 mL (or other appropriate known volume), of spray diluted according to the manufacturer's instructions.
2. Invert the container 100 times (shake vigorously).
3. Allow it to stand for 30 minutes. If, after this time, 'creaming', sedimentation or separation into layers occurs, the water may not be suitable for spraying the pesticide or combination of pesticides you tested.

Sedimentation in this quick test could be caused by pesticide break-down, but this is unlikely unless the chemical is old. Different brands of the same pesticide may react differently because of different additives in each formulation. If you suspect the water is unsuitable, have a sample chemically analysed for salt and hardness levels, then get an informed opinion on its suitability for spraying.

Pesticide compatibility

Wherever possible avoid mixing chemicals unless the mixture is recommended by the manufacturer, or the chemicals have been shown to be compatible through extensive previous experience.

Mixing incompatible pesticides can cause changes in the physical character or chemical structure of one or both pesticides, or produce phytotoxic compounds that will damage the plants. Such changes can result in application problems or reduced efficacy. Avoid mixtures of pesticides if at all possible.

- If considering mixtures of pesticides, follow the manufacturer's instructions and label advice. Only use mixtures where previous experience has proved them satisfactory in a range of situations.

- Where information is unavailable and the use of mixtures is unavoidable, the test procedures outlined above in water quality will provide a **rough guide** for assessment. If the untried mixture is going to precipitate, it is far better to discover the problem when testing, before the chemicals are already in the spray tank. Spray a few plants and check for spray burn or other damage. **Note: The absence of any obvious physical change is not a foolproof indication of absolute compatibility.**

When mixing different formulation types, add them to the tank in the following order:

1. wettable powders and dry flowable dusts, then;
2. suspension concentrations and water soluble formulations, then;
3. surfactants, and lastly;
4. spraying oils and/or emulsifiable concentrates.

Spray drift

Spray drift is the movement of spray particles away from the target area. There are two types of drift, airborne and vapour drift. Vapour drift depends on the environmental conditions, such as temperature and humidity, prevailing at the time of application and for a few days afterwards.

Airborne drift is affected mainly by droplet size and wind speed. The big trade off is in droplet size, because the smaller the droplet the better the coverage but the more susceptible it is to airborne drift. Very fine droplets are desirable to achieve the maximum spray coverage efficiency, however they are also the most susceptible to spray drift and evaporation.

The principles of good spray application require not only good target coverage, but also the reduction of spray drift and the negative impacts it might have on the environment, public health and property.

How to reduce spray drift

- Reducing the application pressure increases the VMD, so fewer small droplets are formed. If the pressure is reduced too much the normal spray angle of the nozzle will be reduced and striping may occur across the spray swath.
- Reducing boom height above the crop will reduce drift but take care not to go lower than the manufacturer's recommendations or striping may occur across the spray swath.

- Most manufacturers have 'low drift' nozzles for use with hydraulic spray booms. A pre-orifice disc in the nozzle tip assembly reduces pressure at the exit orifice and creates larger droplets to reduce drift. These nozzles produce the same flow rate as the standard nozzle but are designed to reduce the percentage of droplets below 100 µm.
- Air inclusion nozzles or air induction nozzles that reduce drift are also available from most manufacturers. They draw air in through aspiration holes in the nozzles and mix it with the spray liquid. The liquid mixture leaving the spray tip contains large air-filled droplets with a VMD of 400 to 600 µm. This eliminates almost all the very fine and fine droplets.

Manufacturers claim that these nozzles are able to provide good spray coverage with large droplet sizes because the air-filled droplets shatter on impact to provide coverage that is comparable to conventional nozzles.

- Air assisted booms have been shown to reduce drift, when compared with a conventional boom, because the forced air stream carries more of the spray down into the crop canopy.
- Shrouded sprayers have been shown to reduce drift by 50%.
- The use of some spray additives can reduce the number of very fine droplets formed, so reducing drift.

Sprayer calibration

One method of calibrating a boom spray is given here. For a mature crop sprayed with a boom spray about 300 L/ha is applied. Much lower rates are applied if air shear misters or CDA equipment are used.

These calibration methods are a guide to ensuring that the equipment is performing correctly. The equipment should initially be set up by someone who is experienced in setting up spray equipment for sweet corn crops. They will help you select the type of equipment you need (pump, diameter of hoses, type of nozzles) and the general setting up of the equipment so it adequately protects your crop. The nozzles are usually set up so that the spray pattern overlaps the next nozzle by at least one-third.

Where to get the DPI&F book *Pesticide application manual,* and DPI&F notes, Chapter 5 page 253

Before calibration, measure the output of each nozzle for a set time, for example 30 seconds, and discard any nozzle that varies more than 10% from the others. You need a good quality, oil-filled, pressure gauge to get accurate pressure readings. When calibrating set the gauge at the pressure you will be using for spraying. More information is available in the DPI&F book *Pesticide application manual* and DPI&F notes.

Boom spray without droppers

To calibrate a boom spray without droppers use the following method. To find the volume of spray applied per hectare you need to know the total output of your nozzles and the time it takes to cover one hectare, that is:

Volume per hectare = output X time to cover 1 ha

Step 1

Output = either the total output of all nozzles

OR

Average output multiplied by the number of nozzles

For example: If your spray rig has 24 nozzles, with an average output of 0.77 L per minute, then:

Output per minute = 24 X 0.77 = 18.48 L/minute

Step 2

Calculate the effective spray width (swath) of the boom.

Swath width (m) = number of nozzles X nozzle spacing (m)

For 24 nozzles at 0.5m apart (nozzles spacing):

Swath width (m) = 24 X 0.5 = 12 m

Step 3

To determine the time to cover 1 ha you need to know the swath width (from Step 2 above) and the time to cover 100 m. Mark out 100 m and note how long it takes the tractor to travel 100 m in the gear and at the engine revolutions at which you will be spraying.

Step 4

$$\text{Time to spray 1 ha} = \frac{\text{10 000 (sq. m/ha) X time to cover 100 m}}{\text{swath width X 100}}$$

Divide this figure by 60 to get the time per hectare in minutes.

For example: If swath width = 12 m (from Step 2); and time per 100 m (Step 3)= 120 seconds then:

$$\text{Time to spray 1 ha} = \frac{\text{10 000 X 120}}{\text{12 X 100}} = \text{1000 seconds}$$

Divide this by 60 = 16.67 minutes per hectare

To work this out using a calculator: 10 000 x 120 = 1 200 000; divide by 12 = 100 000; divide by 100 = 1000 seconds; divide by 60 = 16.67 minutes per hectare.

Step 5

Volume of spray per hectare = output per minute (Step 1) X time in minutes to cover 1 ha (Step 4).

From the examples above:

Volume of spray per hectare = 18.48 X 16.67

Volume /ha = 308 L/ha

Boom spray with droppers

The following example is for calibrating a spray rig using a boom with droppers (Figure 50).

To find the volume of spray applied per hectare you need to know the total output of your nozzles and the time it takes to cover 1 ha:

Volume per hectare = output X time to cover 1 ha

Step 1

Output = the total output of all nozzles

OR

Output = the average output multiplied by the number of nozzles

Example: If your spray rig has 36 nozzles (one on spraying each side of the plant and one over the row), with an average output of 0.46 L per minute, then:

Output per minute = 36 X 0.46 = 16.56 L/minute

Step 2

The swath width is the number of rows sprayed multiplied by the distance between the rows.

Example: If you have 24 row lands you spray 12 full rows with each pass. If the row spacing is 0.85 m and you are spraying 12 rows

Swath width = 0.85 m X 12 rows = 10.2 m

Step 3

To determine the time to cover 1 ha you need to know the swath width (from Step 2) and the time to cover 100 m. Mark out 100 m and note how long it takes the tractor to travel 100 m in the gear and at the engine revolutions at which you will be spraying.

Step 4

$$\text{Time to spray 1 ha} = \frac{\text{10 000 (sq. m/ha) X time to cover 100 m}}{\text{swath width X 100}}$$

Divide this figure by 60 to get the time per hectare in minutes.

Example: If swath width = 10.2 m (from Step 2) and time per 100 m (Step 3) = 120 seconds then:

$$\text{Time to spray 1 ha} = \frac{\text{10 000 sq. m X 120 seconds}}{\text{10.2 X 100}} = \text{1176 seconds}$$

Divide this by 60 = 19.6 minutes per hectare

To work this out using a calculator: 10 000 x 120 = 1 200 000; divide by 10.2 = 117 647.05; divide by 100 = 1176.47 seconds; divide by 60 = 19.6 minutes per hectare.

Step 5

Volume of spray per hectare = output per minute (Step 1) X time in minutes to cover 1 ha (Step 4).

From the examples above:

Volume of spray per hectare = 16.56 L/minute X 19.6 minutes /ha

Volume /ha = 325 L/ha

Amount of chemical per tankful

To determine the amount of product to put into the tank, use these calculations.

Rate quoted as product per hectare:

$$\frac{\text{Tank capacity (L) X recommended rate of product (L/ha or kg/ha)}}{\text{application rate (L/ha)}}$$

Example:

$$\frac{\text{3000 (L) X 2.2 (L or kg/ha)}}{\text{300 (L/ha)}} = \text{22 (L or kg)}$$

OR

Rate quoted as product per 100 L:

$$\frac{\text{Tank capacity (L) X recommended rate of product (L or kg/100 L)}}{100}$$

Example:

$$\frac{\text{3000 (L) X 0.2 (L or kg/ 100 L)}}{100} = \text{6 (L or kg)}$$

Things to remember

To increase the water rate per hectare, you can reduce tractor ground speed, increase pressure or select larger nozzles.

To reduce water rate you can increase tractor ground speed, reduce pressure or select smaller nozzles.

- **Do not** alter the operating pressure outside the range recommended in the manufactures' nozzle charts.
- When checking the flow rate of CDA sprayers it is sometimes easier to disconnect the supply line from the head assembly and collect the spray liquid before the droplets are produced.
- Most manufacturers of hydraulic nozzle boom sprayers offer the option of an electronic controller that monitors ground speed and nozzle flow, and can automatically adjust the pressure so that the predetermined application rate is held constant. The performance of these instruments is usually very reliable but it is advisable to check them occasionally by performing the calibration procedure outlined above.

Cleaning the spray equipment

At the end of each day, sprayers should be flushed out with water to prevent a build up of chemicals. When chemicals are changed or spraying is completed at the end of the season, a more thorough cleaning is required and decontamination may be necessary. Refer to the pesticide label for specific cleaning instructions for most chemicals. The following general procedure may be used:

1. Hose down the inside of the tank and fill to approximately $^1/_3$ full with water.
2. Operate for 10 minutes with water flushing through nozzles.
3. Drain remaining water.
4. Repeat steps 1, 2 and 3.
5. Remove nozzle tips and screens and clean in detergent solution.
6. Fill tank to approximately $^1/_3$ full with water and add a cleaning agent if required, leave overnight, then drain.

Figure 50. *A boom spray with droppers*

Safe storage, use and disposal of pesticides

Pesticides are generally an unavoidable part of farming. Many pesticides pose some threat to people and the environment if they are misused or handled carelessly. This section provides some general guidelines for the safe storage, use and disposal of pesticides, for more detailed information refer to the appropriate local authorities in your state.

Safe storage of pesticides

Chemicals stored on farms must be held in a building or enclosure specifically designed and used for storing chemicals. The main things to consider when planning a chemical storage shed are where to build it and the design of the building.

Choosing a site

The storage shed should be positioned so that it:

- minimises any risk of chemicals affecting people, products or the environment;
- is easily accessible;
- is secure;
- has an adequate water supply.

Storage shed design

The shed must be designed and built in such a way that it meets the following minimum standards, Figure 51. It must:

- be lockable;
- be made of fire resistant material;
- have a sloping concrete floor;
- have a bund wall deep enough to hold at least 25% of the total liquid in the store;
- have a collection pit connected to the store;
- be well ventilated and well lit;
- have non-absorbent shelving;
- be large enough to allow adequate separation of herbicides from other pesticides;
- have a dry-powder fire extinguisher outside but nearby;
- have appropriate warning signs.

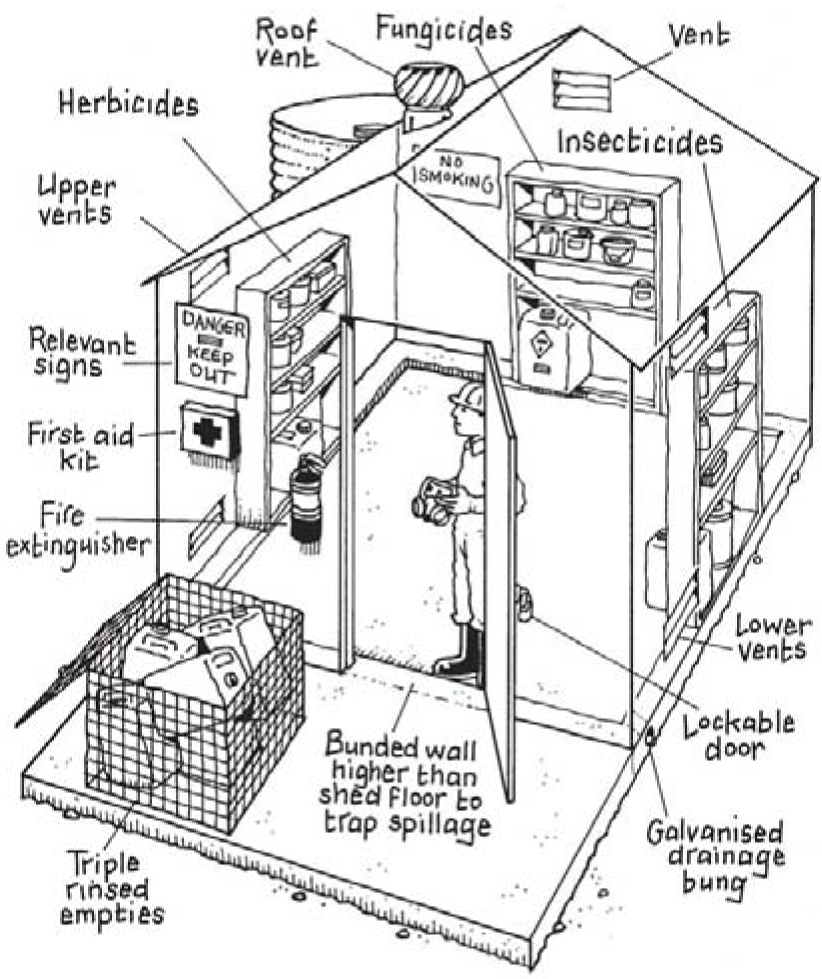

Figure 51. Chemical storage shed layout.
Source: 'Farm Chemical Storage Guide', J. Whitehead and E. Coleman

Safe use of pesticides

READ THE LABEL before opening and using any pesticide, follow the manufacturer's instructions and make sure you know what to do if anything goes wrong.

The Material Safety Data Sheet (MSDS) details the properties of the chemical, the effects on health, precautions to take and what to do in an emergency. You should obtain an MSDS when you purchase the product and keep it close to the chemical in case of an emergency.

If a pesticide is swallowed, immediately contact the **Poisons Information Centre** on **13 11 26**.

Handling pesticides

Always handle pesticides with great care because most have the potential to damage the health of you, your family and/or the environment. This is particularly true when handling the concentrated formulation, but the diluted product should still be handled carefully.

Always handle pesticides in a well ventilated area and triple-rinse emptied containers.

Do not take risks, use common sense when handling pesticides.

Protective clothing

Always wear protective clothing when handling and using pesticides. The type of protection required will depend on the pesticide being used. The following is a guide to the Do's and Don'ts of pesticide handling.

DPI&F note, *Using agricultural pesticides 3. Safe storage and handling*, www.dpi.qld.gov.au

Do's:

- do cover as much of your body as possible;
- do use washable fabric overalls, disposable overalls, or waterproof clothing;
- do wear goggles and a close fitting respirator with the correct filter for the chemical you are using;
- do wear a hat;
- do wear unlined rubber gloves;
- do wear trouser legs outside your boots;
- do soak protective clothing in bleach overnight and wash after each use.

Don'ts:

- don't wear leather or cloth material that will absorb pesticide;
- don't wash protective clothing with family laundry.

Applying pesticides

Remember the following points when applying pesticides:

- read the label;
- make sure that the pesticide you are using is registered in your state, on your crop for the pest you are trying to control;
- check the withholding period;
- before spraying, use clean water to check for leaks or blockages and calibrate your application equipment if this has not been done recently;
- do not spray in windy conditions if the wind is likely to blow the spray onto non-target areas.

After spraying

After spraying do the following:

- thoroughly clean the spray equipment in an area where runoff will not cause problems;
- remove protective clothing then have a shower as soon as possible;
- make sure you wash before eating, drinking or smoking.

Safe disposal of pesticides and their containers

A major problem facing users of pesticides is the disposal of empty containers and unwanted chemicals.

ChemClear
Phone: 1800 008 182 or
www. chemclear.com.au

ChemClear is an industry-funded program for on-going collection and disposal of unwanted registered chemicals.

A method for safe disposal of used pesticide containers is provided by drumMUSTER. It is the national program for the collection and recycling of empty, cleaned, non-returnable chemical containers used in crop production and on-farm animal health. It was developed by several organisations including the National Farmers' Federation (NFF), the National Association for Crop Protection and Animal Health (Avcare), the Veterinary Manufacturers and Distributors Association (VMDA), and the Australian Local Government Association (ALGA).

How does drumMUSTER work

Since February 1999, farm chemical users have paid a 4 cents per litre or kilogram levy on crop production and on-farm animal health products sold in non-returnable chemical containers over one litre or kilogram. This levy funds the drumMUSTER program and is available to reimburse participating councils for all agreed costs incurred in running a drumMUSTER collection.

For more information about drumMUSTER collections, contact your local council or visit the drumMUSTER website on the internet at www.drummuster.com.au and go to the collection calendar

The drumMUSTER program has two objectives:

- To reduce the amount of packaging at the source by encouraging manufacturers to adopt alternatives such as bulk or re-fillable containers, new packaging technology and formulations including water soluble sachets, gel packs and granules.
- To that ensure non-returnable crop production and animal health product containers have a defined route for disposal that is socially, economically and environmentally acceptable.

The drumMUSTER program was set up to provide councils across Australia with financial and planning support so that implementation is cost-neutral. Further, it provides a service to ratepayers so that:

- fewer bulky containers end up as landfill in rubbish dumps;

- farmers are able to dispose of chemical containers;
- the community has a cleaner environment.

A few chemicals may not be eligible for disposal through drumMUSTER. Eligibility is indicated by a drumMUSTER eligible container logo or the drumMUSTER eligible container re-use logo.

Preparing containers for collection

The drumMUSTER program is only for **clean, empty** containers. The container must be cleaned to meet the Agsafe Cleanliness Standards. Containers will not be accepted by drumMUSTER if any residue is visible on the inside or outside of the container, including threads and caps. The container should still have the labels on so inspectors can identify the material being handled.

The brochure '*The Agsafe Standard For Effective Rinsing Of Farm Chemical Containers*' will provide more details and is available from local resellers.

Once you have emptied a chemical container, immediately clean the container and store it in a safe location until you can deliver it to a drumMUSTER collection. Containers must be flushed, pressure-rinsed or triple rinsed and allowed to dry before being taken to the collection centre.

Do not puncture plastic 20 L containers included in reconditioning/re-use programs, or displaying the RE-USE logo.

Puncture steel containers by passing a steel rod or crowbar through the neck/pouring opening and out through the base of the container.

Do not place caps on the container, however they may be brought separately to a collection.

Postharvest temperature management

Careful handling and postharvest temperature management of sweet corn is critical to ensure that you can put a top quality product into the market place and be confident that it will not breakdown in the market chain.

Cooling

Sweet corn deteriorates very quickly at high temperatures as sugar is converted to starch, so it is very important to remove field heat and reduce temperature to 0°C as soon as possible, preferably within one hour. Take cobs to the shed as soon as possible after harvesting. After packing, keep the sweet corn cool for transport to market. Pest and disease problems develop much slower at low temperatures.

Because sweet corn is so perishable, it does not store well and should be consumed as soon as possible after harvest, before too much sugar is converted to starch. There are three common ways to cool sweet corn.

Hydro-cooling. This is the most efficient way of cooling sweet corn. Cold water is showered over produce, cooling it quickly. To be efficient, hydro-cooling needs high volumes of cold water (close to 0°C) moving over as much of the surface of produce as possible. Produce may be moved through the cold water shower on a conveyor or be cooled in batches. Hydro-cooling does not dry out product and helps keep humidity high.

Seek specialist advice before buying a cooling system as there are several important design features you need to consider.

Vacuum cooling. This method is the fastest and most energy efficient form of pre-cooling. Product is placed inside an airtight chamber and the air is evacuated. This lowers the pressure and the boiling point of water, so water on the surface of the product rapidly evaporates, removing the field heat. Vacuum cooling is only efficient on products with a high surface area/volume ratio. As evaporation removes water from the product causing some drying, a modified system called HydroVac reduces water loss by showering the product during cooling and has been very efficient in cooling sweet corn.

Vacuum coolers are not widely used because they are expensive to buy and operate and can only be used on a limited range of products.

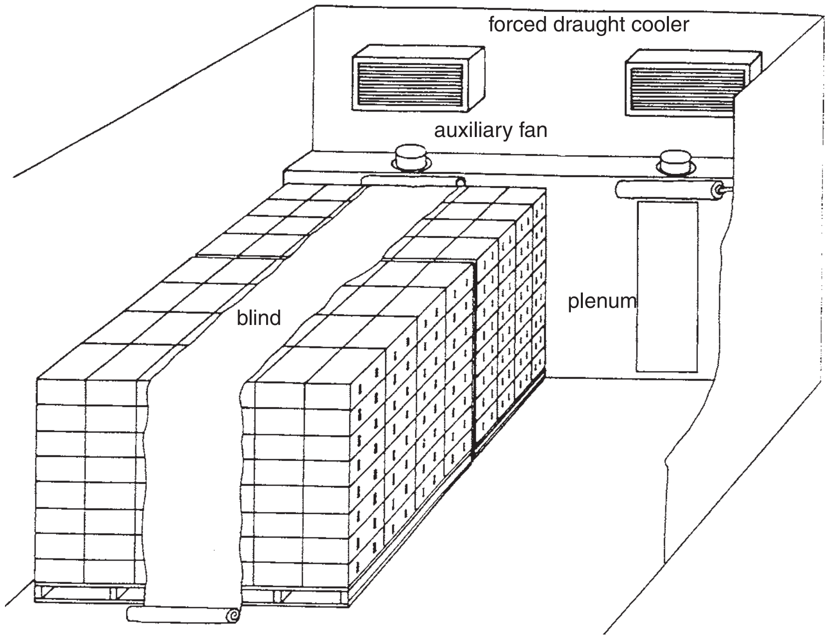

Figure 52. Pallets of produce in a forced-air cooling room

Forced-air cooling. Cool air is sucked through packages stacked with the ventilation slots aligned. This allows air to move into a central low pressure channel and plenum chamber and return to the room via the cooling coils, Figure 52. Older systems may cause some drying of the cob husks, but newer systems maintain high relative humidity, avoiding this problem. It is also used to maintain low temperatures in pre-packs.

Transport

Sweet corn is sometimes top-iced in boxes to keep corn cool whilst in transit. Use refrigerated trucks to transport sweet corn to market to help keep cobs cool. All products in the truck should be pre-cooled before loading.

Top icing involves placing crushed ice, by hand or machine, over the top of cobs in polystyrene packages. Icing is particularly effective on dense products and palletised packages that are difficult to cool with forced air. For liquid icing, a slurry of water and ice is injected into produce packages through vents or handholds without removing the packages from pallets and opening their tops. Because of its residual effect, icing methods work well with high respiration commodities such as sweet corn.

Sweet corn should be transported in refrigerated containers at 0° to 2°C. Refrigerated containers should contain the following equipment maintained in good working condition:

- fluming; (This directs cool delivery air evenly over the top of the load.)

- floor channels running the length of the container; (Floor channels allow return air to move back to the refrigeration unit.)
- a bulkhead around the evaporator. (This improves the movement of return air to the refrigeration unit and reduces the risk of freezing.)

Avoid stabilising sheets placed through the load. These sheets prevent air movement through the load, particularly if the packages are not palletised.

Refrigeration systems in rail wagons and road transports are designed to maintain temperature, not to cool fruit and vegetables. Print-out temperature recorders should be fitted to all refrigeration containers.

The *Code of practice for the road transportation of fresh produce 1996/2000* is a guide to road transport. It is available through:

http://www.auftac.com.au/mainframeset.html

Storage

Careful temperature management is critical to maintain the quality of sweet corn. Under ideal conditions (95 to 100% humidity and storage temperature at 0°C) sweet corn may be stored without significant loss of quality for 4 to 8 days. However, quality rapidly deteriorates if cobs are allowed to return to room temperature. Table 72 shows shelf life based on its percentage sucrose (sugar) for normal (su) and supersweet (sh_2) sweet corn at two temperatures. A reduction in sugar content reflects a reduction in the shelf life of sweet corn.

Table 72. Sweet corn shelf life at two temperatures based on percent sucrose

Temp°C	Hours from harvest					
	0 hrs (at harvest)	24 hrs	48 hrs	72 hrs	96 hrs	Sweet corn genotype
4°C	14.4	10.0	12.0	11.0	9.9	su
	36.5	32.0	31.0	32.0	33.0	sh_2
24°C	14.4	5.7	5.0	3.5	2.4	su
	36.5	29.0	27.0	21.0	13.5	sh_2

Source: Garwood et al (1976)

It is important to maintain a high humidity (95 to 100%) in cooling and storage to prevent desiccation of wrapper leaves and kernels. A hydro-cooling process helps to achieve this.